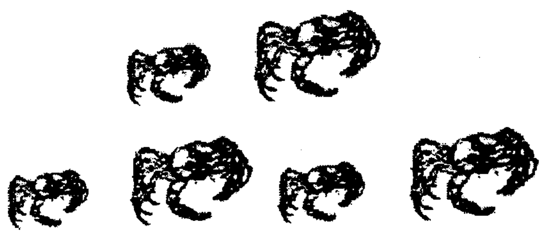
STOCK ASSESSMENT AND FISHERY EVALUATION REPORT FOR GOLDEN CRAB

FISHERY MANAGEMENT PLAN FOR THE GOLDEN CRAB FISHERY OF THE SOUTH ATLANTIC REGION

VOLUME I



MAY 1999

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prepared by the
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1.0 INTRODUCTION

The *Guidelines for Fishery Management Plans (602 Guidelines)* published by the National Marine Fisheries Service (NMFS) require that a stock assessment and fishery evaluation (SAFE) report be prepared and reviewed annually for each fishery management plan (FMP). The SAFE reports are intended to summarize the best available scientific information concerning the past, present, and possible future condition of the stocks and fisheries under federal management. Appendix A to the *Guidelines* lists the desired components of SAFE reports as follows: 1) information on which to base harvest specifications; 2) information on which to assess the economic and social condition of persons and businesses that rely on recreational and commercial use of fish resources, including fish processing industries; and 3) any additional economic, social, and ecological information pertinent to the success of management or the achievement of objectives of each FMP.

The SAFE report for the Golden Crab fishery managed under the Fishery Management Plan for Golden Crab in the South Atlantic was compiled by South Atlantic Council staff with input from NMFS SERO and NMFS SEFSC. Our goal was to include the most recent information on issues that have been raised or are likely to be raised during the Council's review of the golden crab stock and fishery. The detailed information is found in the attached reports and we have only attempted to extract a very brief overview for inclusion in Sections 2, 3 and 4.

A very summary overview of stock status is presented in Section 2.0 Overview of Stock Assessment. Overviews of economic and social status of the fishery are presented in Section 3.0 Fishery Evaluation. This section contains material from the Council's Sustainable Fisheries Act Amendment describing fishing communities. Ecosystem considerations are presented in Section 4.0 Ecosystem Considerations using material from the Council's Habitat Plan and Habitat Amendment. These sections rely very heavily on the identified Council documents and the following appendixes:

Appendix A. Results of Literature Search.

A computer search of published literature was conducted. These results, along with the literature cited sections of the papers included in Appendix A through Appendix Q, should provide much of the pertinent literature.

Appendix B. List of Contributions to SAFE as Provided by NMFS SERO.

This list includes suggested documents for the SAFE report. All of these reports have been included in the SAFE report.

Appendix C. Fishery Status Report Through 1998.

NMFS has not provided the report as of this date.

Appendix D. Annual Report Tracking Permit Transactions.

This report shows the number of permits over time from the NMFS Southeast Permits Office.

Appendix E. Economic Assessment Report.

NMFS has not provided the report as of this date.

Appendix F. Summary Update of the Golden CrabTrip Report. Logbook, Trip Interview Data and Preliminary production Model Analysis (NMFS-SEFSC-PRD-97/98-31).

This report was prepared for the Council's Golden Crab Advisory Panel in 1998 by Douglas E. Haper and Gerald P.Scott. It describes the logbook program for the golden crab fishery and provides a summary of the data derived from the logbooks through 1998 (NMFS, Southeast Fishery Science Center). This report was used to summarize the stock status given that the 1999 report was not received.

Appendix G. Golden Crab Fishery Development (SERO-ECON-98-15).

The golden crab fishery in the Southeast region is described in this paper by William O. Antozzi, focusing on how economic forces are affecting the development of this fishery (NMFS, Southeast Regional Office).

Appendix H. Golden crab Landings and Exvessel Prices (SERO-ECON-98-17).

This report produced by John Vondruska of the Fisheries Economic Office in the Southeast Region is a preliminary assessment of monthly golden crab harvest data from January 1995 through February 1998.

Appendix I. Golden Crab Progress Report (SERO-ECON-98-01).

Prepared in October of 1997 by William O. Antozzi, this report provieds a breif overview of the golden crab fishery including number of vessels, an update of landings, and exvessel prices as of May 1997 (NMFS, Southeast Regional Office).

Appendix J. New Fishery Management and Fishermen (Fathom Vol.7, No.1).

Fathom, a Florida Sea Grant Publication, describes the golden crab fishery from its inception and early management by the Council.

Appendix K. Golden Crab: Growing a Fishery the Right Way (National Fisherman, September 1995).

This 1995 National Fisherman article discusses the golden crab fishery and the Nielsen family who pioneered the new golden crab fishery (Septmber, 1995).

Appendix L. Geryonic Crabs and Associated Continental Slope Fauna: A Research Workshop Report (January 1990).

A report by William J. Lindberg (University of Florida) and Elizabeth L. Wenner (South Carolina Department of Natural Resources) summarizing the workshop presentations and discussions of a group that met in January 1998 to share regional comparisons, to inform the commercial fishing industry and resource agencies, and to provide guidance for future research investments (Sea Grant Project No. R/LR-B-17).

Appendix M. In Situ Estimates of Density of Golden Crab, *Chaceon fenneri*, from Habitats on the Continenetal Slope, Southeastern U.S. (1990).

This paper by Elizabeth L. Wenner and Charles A. Barans describes observations made from a submersible from the Continental Slope in the Southeatern U.S. on the density and habitats of golden crab (Bulletin of Marine Science, Vol.46, No.3, 1990).

Appendix N. Exploration of Golden Crab, *Geryon fenneri*, in the South Atlantic Bight: Distribution, Population Structure, and Gear Assessment (1987).

This study by Elizabeth L. Wenner, Glenn F. Ulrich, and John B. Wise was conducted to determine the potential of the golden crab fishery, compare trap designs, and to describe distribution and biology of the golden crab (Fishery Bulletin, Vol.85, No.3, 1987).

Appendix O. Reproductive Ecology of Female Golden Crabs, *Geryon fenneri* Manning and Holthuis, from Southeastern Florida (1998).

Deepwater female golden crabs from southeastern Florida were examined to collect data on the reproductive cycle, fecundity, mating and size at sexual maturity. This paper was written by Robert B. Erdman and Norman J. Blake (Journal of Crustacean Biology, Vol.8, No.3, 1988).

Appendix P. The Golden Crab (*Geryon fenneri*) Fishery of Southeast Florida (1988).

In Febuary of 1986, Robert B. Erdman and Norman J. Blake began a study of the biology of the golden crab collecting data from the southeastern Florida fishery to examine reproductive biology, size and weight relationships, trap design and catch per unit effort.

Appendix Q. Market Report: North Pacific Crab (National Fisherman, October 1998).

This report from National Fisherman describes the influence the Japanese market has on U.S. crab prices.

2.0 OVERVIEW OF STOCK ASSESSMENT

2.1 Stock Identification

The following text is directly from the Golden Crab Fishery Management Plan (SAFMC, 1995):

The following text is from Erdman (1990):

"The golden crab, *Chaceon fenneri*, is a large gold or buff colored species inhabiting the continental slope of Bermuda (Luckhurst, 1986; Manning and Holthuis, 1986) and the southeastern United States from off Chesapeake Bay (Schroeder, 1959), south through the Straits of Florida and into the eastern Gulf of Mexico (Manning and Holthuis, 1984, 1986; Otwell et al., 1984; Wenner et al., 1987).

Prior to its description, previous records referred to this species as either the red crab *C. quinquedens* or the similar gold colored *C. affinis*, which is endemic to the northeast Atlantic Ocean (National Marine Fisheries Service, 1986; Manning and Holthuis, 1984). Its recognition as a new species was a direct result of exploratory fishing in the eastern Gulf of Mexico in hopes of establishing a new deep-sea crab fishery in this area (Otwell et al., 1984).

Reported depth distributions of *C. fenneri* range from 205 m off the Dry Tortugas (Manning and Holthuis, 1984) to 1007 m off Bermuda (Manning and Holthuis, 1986). Size of males examined range from 34 to 139 mm carapace length (CL) and females range from 39 to 118 mm CL. Ovigerous females have been reported during September, October and November, and range in size from 91 to 118 mm CL (Manning and Holthuis, 1984, 1986)."

The following text is directly from the Golden Crab Fishery Management Plan (SAFMC, 1995):

"The management unit is the population of golden crab occurring within the South Atlantic Council's area of jurisdiction along the U.S. Atlantic coast from the east coast of Florida, including the Atlantic side of the Keys, to the North Carolina/Virginia border. Red crab and Jonah crab are included in the fishery but not in the management unit because regulations in this plan only address golden crab at this time. Although all three species of crab are also harvested in the Gulf of Mexico and Mid-Atlantic/New England waters, the Council concluded the populations are sufficiently separated from one another to be managed separately."

2.2 Biology

The following Section 3 information is directly from the Golden Crab Fishery Management Plan (SAFMC, 1995) [Note: Figures are from the Golden Crab FMP]:

3.1.2 Growth

3.1.2.1 Size and Weight Relationships

The following text, Table 3 and Figures 4-6 are from Erdman (1990):

"Throughout the sampling period, the catch of male crabs greatly outnumbered that of females. Cumulative size frequency distributions of 508 males and 347 female *C. fenneri* examined (Figure 4) indicate a unimodal distribution for each sex with no suggestion of distinct year classes. Males are considerably larger than females, with overlap between the largest females and smallest males. Carapace widths of male crabs ranged from 111 to 190 mm with a mean CW of 158 mm, while females ranged from 89 to 156 mm CW with a mean CW of 123 mm. Animals smaller than 89 mm CW were not collected, possibly due to bias associated with trap design and the presence of escape rings. Fishing depths also precluded analysis of

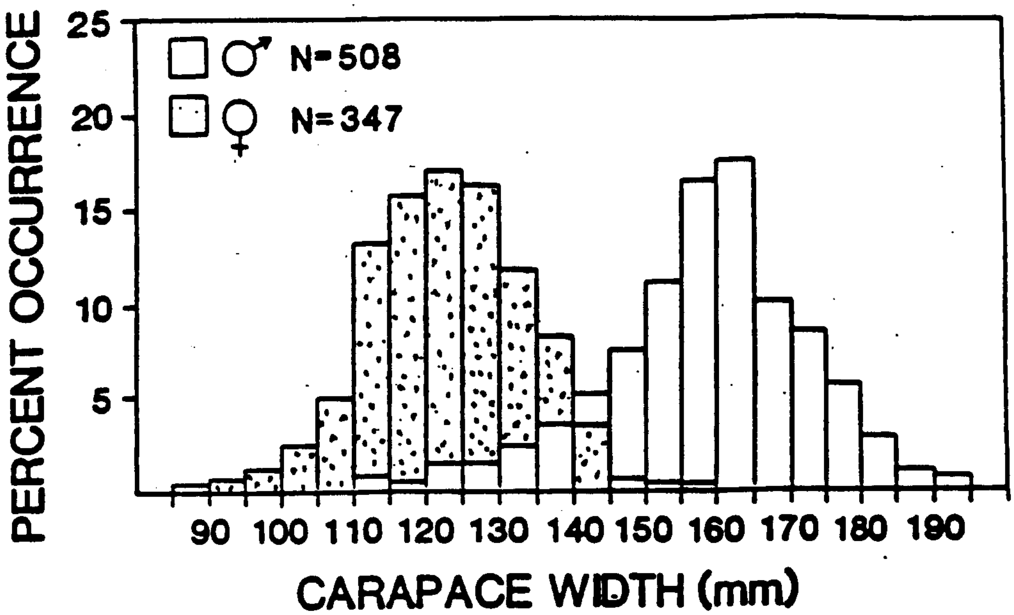


Figure 4. Cumulative size frequency distribution of male and female *Chaceon fenneri* collected during the period of February, 1986 through January, 1987 from southeast Florida. N represents the number of individuals examined.

Table 3. Linear and geometric mean (GM) functional regression equations of carapace length (CL) and weight (WT) on carapace width (CW) for male and female *Chaceon fenneri*. Size units are in mm and weight units are in gm. All linear regression equations are significant at $p<0.05$.

Linear equation	N	R^2	GM equation
Males			
CL = -5.99 + 0.81CW	262	0.89	CL = -14.30 + 0.92CW
WT = -2132.45 + 20.64CW	262	0.87	WT = -2369.34 + 22.15CW
Females			
CL = -4.28 + 0.86CW	193	0.88	CL = -13.19 - 0.93CW
WT = -790.63 + 9.92CW	136	0.87	WT = -877.09 - 10.62CW
Combined sexes			
CL = -5.19 + 0.86CW	455	0.95	CL = -8.61 + 0.88CW

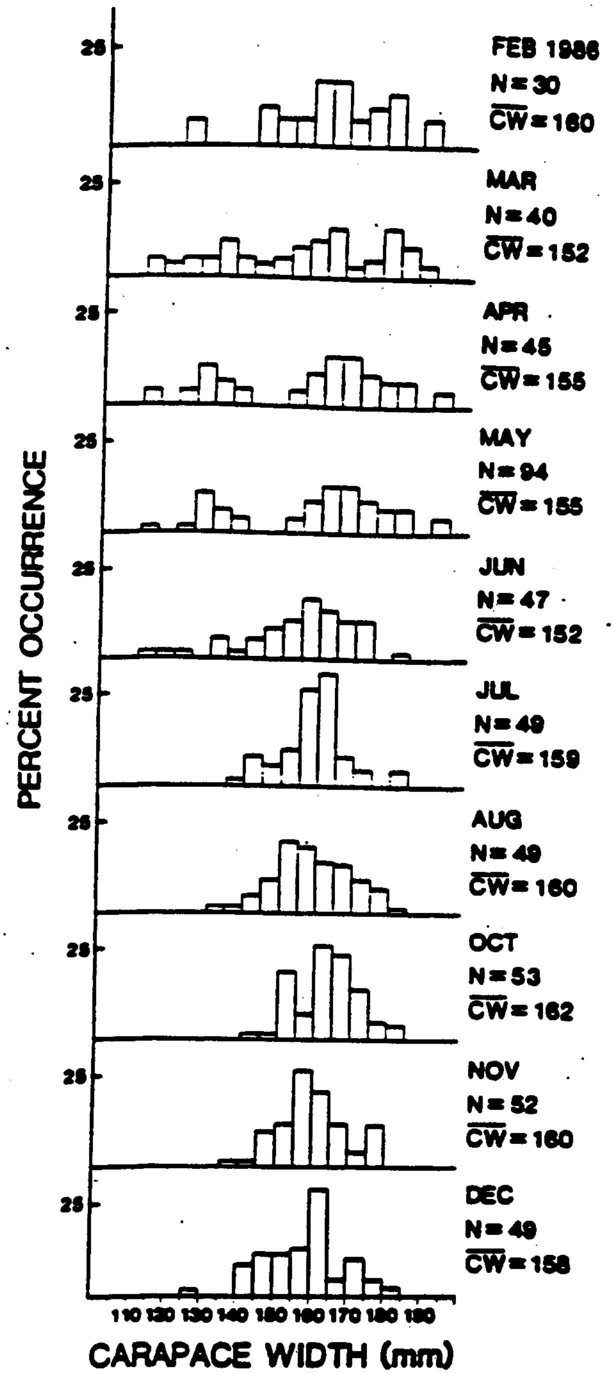


Figure 5. Monthly size frequency distributions of male Chaceon fenneri from southeast Florida.

segregation by size with sex and depth as has been reported for other *Chaceon* species (see Beyers and Wilke, 1980; Gerrior, 1981; Intes and Le Loueff, 1976; Haefner, 1978 and Wenner et al., 1987). Monthly size frequency distributions of male *C. fenneri* are shown in Figure 5. Monthly mean carapace widths ranged between 152 and 162 mm; however, the incidence of smaller males decreased beginning in July 1986, coincidental with the fitting of escape rings in all traps. Although the present data set precludes statistical analysis of the effect of escape rings, the absence of smaller males and females in the overall catch was apparent following installation of escape rings in all traps. This suggests that smaller individuals may exit the trap once all bait is consumed.

Morphometric relationships for CL vs. CW were based on 262 males and 193 females. Linear and GM functional regression equations for each sex are shown in Table 3. ANCOVA indicated no significant differences between male and female CL vs. CW equations ($p<0.05$), therefore linear and GM functional regression equations of CL vs. CW were calculated for both sexes combined (Table 3).

The weight frequency distribution of 262 males and 136 non-ovigerous females is shown in Figure 6. Weight of male crabs greatly exceeded that of females, ranging from 280 to 1930 g, with a mean weight of 1116 g. Mean weight of females was 449 g, ranging from 207 to 800 g. Although weights of both sexes show a unimodal distribution, the greater incidence of females in a narrower range of weight classes is due to the variation in body weight associated with the various phases of oogenesis. Because of obvious size differences between sexes, WT vs. CW relationships were calculated separately for each sex and are shown in Table 3."

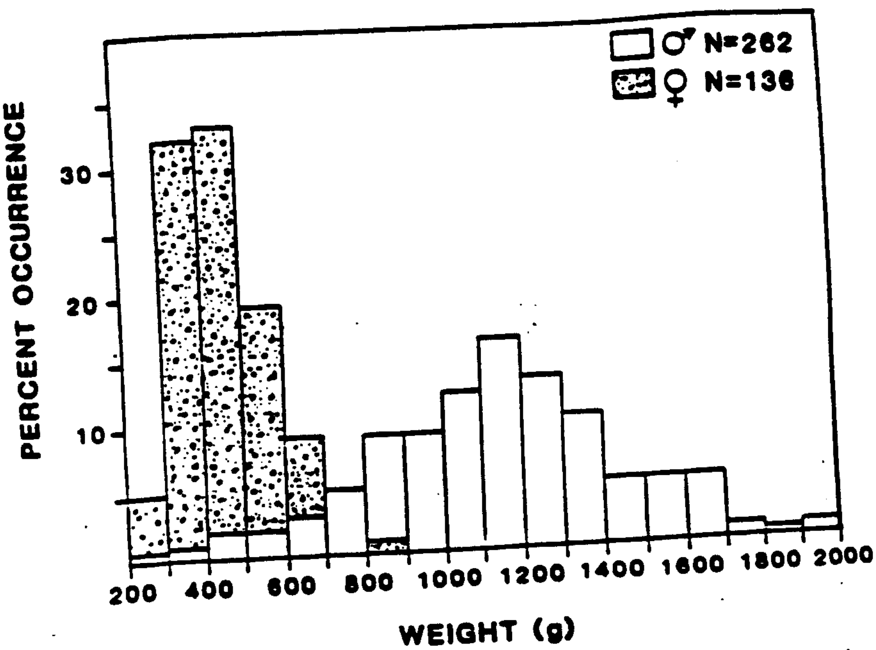


Figure 6. Cumulative weight frequency distribution of male and female <u>Chaceon fenneri</u> collected during the period of February, 1986 through January, 1987 from southeast Florida. N represents the number of individuals examined.

Information from the South Atlantic Bight (text, Figure 2 and Table 4 from: Wenner et al., 1987) indicated that:

"The 3,217 golden crabs which were measured ranged from 85 to 193 mm in carapace width and weighted from 100 to 2,109 g. Average weight of male golden crab collected during the study was 927 g (s = 373.448, n = 1,640) while average weight of females was 443 g (s = 289.385, n = 86). Carapace width-frequency distribution for *G. fenneri* gave modes at 155 mm for males and 100 mm for females (Fig. 2). The largest crab collected measured 193 mm and weighed 2,091 g.

Linear least-squares and functional regression equations (Ricker 1973; Sokal and Rohlf 1983) relating carapace length and live wet body weight with width are in Table 4. Width-weight relationships were calculated from data on individuals that were not missing appendages.

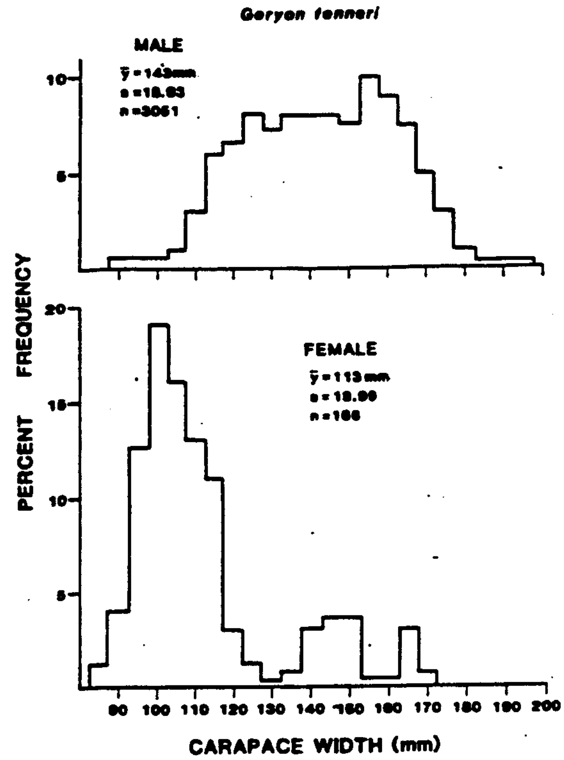


FIGURE 2.—Width-frequency distributions of male and female *Geryon fenneri* caught in traps. ȳ = mean; s = standard deviation; n = number of individuals.

TABLE 4.—Least-square linear and geometric mean functional regression equations of carapace length (CL) and live body weight (WT) on carapace width (CW) for each sex of *Geryon fenneri*. Length and width units are millimeters while weight units are kilograms. All least square regressions were significant at $\alpha = 0.05$.

Sex	Least squares equation	n	r^2	GM functional equation
Male	CL = −9.5 + 0.9 CW	3,042	0.95	CL = −11.9 + 0.9 CW
	$\log_{10}$ WT = −4.74 + 3.54 ($\log_{10}$ CW)	1,453	0.94	$\log_{10}$ WT = −4.99 + 3.66 ($\log_{10}$ CW)
Female	CL = 4.0 + 0.8 CW	141	0.92	CL = 0.7 + 0.8 CW
	$\log_{10}$ WT = −3.97 + 3.14 ($\log_{10}$ CW)	74	0.91	$\log_{10}$ WT = −4.27 + 3.29 ($\log_{10}$ CW)

3.1.2.2 Molting

The following text and Figure 7 are from Erdman (1990):

"No discernible molting pattern was observed for male *C. fenneri*. Fewer than 3% of the 508 crabs examined were observed in the immediate premolt stage (SO), while less than 10% showed the clean bright gold carapace indicative of recent molting. Although asynchronous molting is possible, meat of butchered males shows a watery texture during March and April that suggests physiological changes occurring prior to the onset of molting (R. Nielsen, commercial fishermen, pers. comm.). No changes in external carapace condition were noted during this period.

Conversely, female crabs showed two period of molting activity. During August and October, 1986, 33% of females examined were in the immediate premolt stage (SO) (Figure 7). Premolt females ranged in size from 89 to 118 mm CW. Females in the immediate post-molt stage (SN) and early intermolt stage (HN) were collected during October through December. Size ranges of recently molted females was between 110 and 139 mm.

Additional molting activity was also observed during January 1987, when 17% of females observed were in the premolt stage. Carapace widths of premolt females was between 103 and 123 mm CW. This molt period was not as pronounced as that observed during late summer and early fall. However, recently molted females (stage HN) were present in the catch during the period of March through May 1986, suggesting that these animals may have molted during the pervious late winter or early spring."

Information from the South Atlantic Bight (Wenner et al., 1987) indicated that:

"Most (80%) of the 3,183 male and female *G. fenneri* were in the intermolt stage. Less than 1% of the 3,041 male golden crab showed evidence of having recently molted. The incidence of imminent or recently molted female golden crab was higher that that observed for males, with four individuals classified as premolt (soft-old) and two in the newly molted (soft-new) condition.

Most (95%) of the 3,183 *G. fenneri* examined for molt condition had blackened abraded areas on the exoskeleton, indicative of damage by chitinolytic bacteria. Exoskeleton damage was most prevalent on individuals in the intermolt (75%) and premolt (19%) condition."

3.1.2.3 Growth

The following text is from Erdman (1990):

"Although the data collected during this study was insufficient for the analysis of growth patterns of *C. fenneri*, a discussion of growth in deep-sea crustaceans is warranted due to the important biological and fishery implications. Growth is generally expressed as an increase with time in length, volume or weight (von Bertalanffy, 1938). In crustaceans, growth is discontinuous and involves a series of molts (ecdyses) during which the rigid exoskeleton is shed and replaced by a new and larger one. However, this loss of integument results in the loss of all calcified structures thereby preventing the analysis of annual rings in persistent structures such as the shells of mollusks and the otoliths of fish. A second complication is that many types of tags are lost during molting, thus tag and recapture studies must be planned and executed accordingly (Hartnoll, 1982).

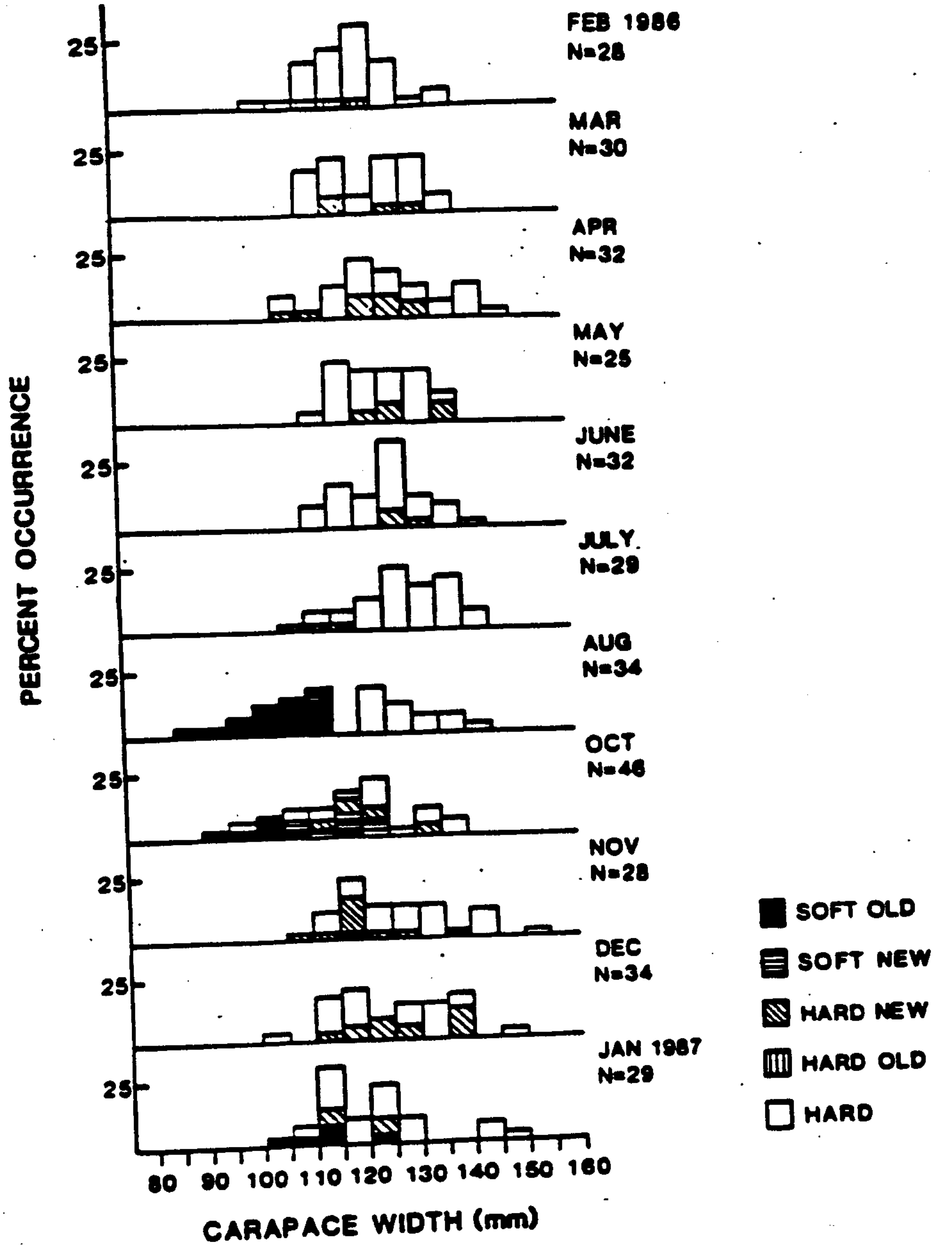


Figure 7. Monthly size frequency distributions of female Chaceon fenneri showing molt stages. Key to each stage is given in the figure. N represents the number of individuals examined.

The examination of growth in crustaceans encompasses the analysis of two major components; the molt increment or increase in size at each molt, and the intermolt period or time between successive molts. With increased size, the molt increment usually decreases and the intermolt period commonly increases (Kurata, 1962; Hartnoll, 1982). However, between sexes, females generally show a more drastic change in the growth format at the onset of sexual maturity. This is usually attributed to the energetic cost of reproduction and the accompanying period of egg brooding (Hartnoll, 1985).

Besides changes associated with size, sex and maturity, environmental factors such as temperature, light and food supply have also been shown to affect the growth format of crustaceans (Hartnoll, 1982). The majority of growth studies have been conducted under laboratory conditions where these determinants have been selectively controlled which further complicates analysis of actual growth in natural populations (Kurata, 1962). Studies of the later type are few in number and are limited to tag and recapture studies of species where commercial fisheries provide significant returns (Haefner, 1985).

Growth in deep-sea crustaceans is generally quite slow (Childress and Price, 1978; Roer et al., 1985). This is not surprising when one considers the low metabolic rates of deep-sea organisms as compared to those of species living elsewhere (Smith and Teal, 1973; Torres et al., 1979). The low rate of metabolic processes have been proposed as an adaptive response to the decrease in biomass and food supply that are characteristic of increased depth (Rowe, 1983). In particular, slow growth in deep-sea crustaceans may be attributed to a decrease in the molt increment, and increase in the intermolt period, or a combination of both (Roer et al., 1985).

Melville-Smith (1989) has developed a growth model for male *C. maritae* which indicates that growth in that species is extremely slow. The model is based on growth data from juvenile *C. quinquedens* (Van Heukelem et al., 1983), and tag and recapture data of adult *C. maritae* greater than 50 mm CW collected from the commercial fishery off South West Africa/Manibia. In general, smaller males (50-100 mm CW) showed an intermolt period of between 0.5-2.0 years, while larger males (100-150 mm CW) exhibited intermolt periods of between 3-5 years. The model also predicts age from the growth data and suggest that male *C. maritae* of 165 mm CW may be over 25 years old.

The low numbers of premolt and post-molt *C. fenneri* observed in this study also suggests that growth in this species is quite slow. Females showed a greater incidence of molting activity than males, but total numbers of both sexes in the SO, SN and HN stages comprised less than 12 percent of all individuals examined. Although *C. fenneri* reaches a greater maximum size than the majority of Geryonidae, the growth model developed for *C. maritae* may be applied in general terms. As the present minimum size of male *C. fenneri* harvested by the commercial fishery is 130 mm CW, the model suggests that animals of this size enter the fishery in their sixteenth year. Larger males exceeding 170 mm CW may well be over 30 years of age."

3.1.3 Reproductive Biology

The following background is from Erdman (1990):

"Reproductive cycles of marine invertebrates may be classified as rhythmic or continuous. Rhythmic patterns, which may be weekly, monthly, annual or biennial, involve a distinct gametogenic cycle. This includes the production and release of gametes followed by a period of inactivity during which energy reserves accumulated and gonad tissue regenerates prior to the onset of the next successive cycle. Thus, most reproductively active individuals of a population will reproduce synchronously when environmental conditions are correct (Giese, 1959; Giese and Pearse, 1974). Precise timing requires that initiation and regulation of gonad development is in synchrony with changes in the external environment, leading to the production of new individuals during conditions which are most optimal for their survival (Sastry, 1975).

Continuous reproduction implies a successive series of gametogenic cycles by each individual. As there is no synchrony between individuals, the population appears to be reproducing continuously with the regulation of gonad development varying among each individual (Giese and Pearse, 1974).

The reproductive cycle is affected by exogenous factors such as temperature, photoperiod, salinity, and food supply. Temporal changes in these factors act as "zeitgebers" (triggers) that synchronize gametogenesis such that reproduction occurs under favorable conditions (Giese and Pearse, 1974). considering the environmental consistency of the deep sea, continuous reproduction patterns are expected (Thorson, 1950; Scheltema, 1972). This pattern had been reported in a variety of deep-sea invertebrates: branchiopods (Rokop, 1974), bivalve mollusks (Sanders and Hessler, 1969; Rokop, 1974), isopods (Sanders and Hessler, 1969; Rokop, 1977), amphipods (Rokop, 1977), decapods (Haefner, 1977; Tyler et al., 1985; Melville-Smith, 1987c), and ophiuroids (Rokop, 1974; Grant, 1985). In virtually all of these studies, the absence of seasonality has been proposed to be responsible for the continuous patterns observed.

Annual reproductive patterns in the deep sea have only been reported for a few species of bivalve mollusks (Lightfood et al., 1979), isopods (George and Menzies, 1967, 1968), decapods (Hartnoll and Rice, 1985) and ophiuroids (Schoener, 1968; Lightfood et al., 1979). However, the data presented have often been questionable (presence/absence of ovigerous females; George and Menzies, 1967, 1968) and the recognition of specific "zeitgebers" has proved to be quite difficult if not impossible.

Although continuous reproduction may predominate in the deep sea, comprehensive data on many deep-sea invertebrates remains scarce. Certain species may show annual patterns, yet it is obvious that the mode of development, evolutionary history, phylogenetic status and trophic dynamics of the species in question must be examined to ascertain the significance of this type of reproduction pattern in the deep sea."

Golden crab reproductive biology was also studied in the South Atlantic Bight by Wenner et al. (1987). Their results are also included in Sections 3.1.3.3 and 3.1.3.4.

3.1.3.1 Reproductive Cycle

The following text and Figures 12-14 are from Erdman (1990):

"The monthly incidence of ovigerous females examined indicates an annual reproductive cycle with a single batch of eggs produced each year (Figure 12). Oviposition begins in mid-August and continues through early October. Thirty-three percent of females collected in August were ovigerous and had spent/redeveloping ovaries, while 17% had mature ovaries prior to oviposition. In October, 29% were ovigerous with ovaries in either spent/redeveloping or early developmental stages, while 8% had mature ovaries (Figure 13).

Eggs are light purple or burgundy after oviposition, gradually becoming dark purple and purple=brown prior to hatching. They are carried from approximately six months after which larvae hatch during late February and March. Seven percent of females examined in February and 57% from March had egg remnants on the pleopods. Larvae were hatched from two ovigerous females held in the laboratory during early March, but larval culture was not successful.

Analysis of mean monthly oocyte diameter further illustrates the annual reproductive cycle of *C. fenneri* (Figure 14). The minimum oocyte diameter recorded in October coincided with the greatest incidence of ovigerous females with redeveloping and early stage ovaries.

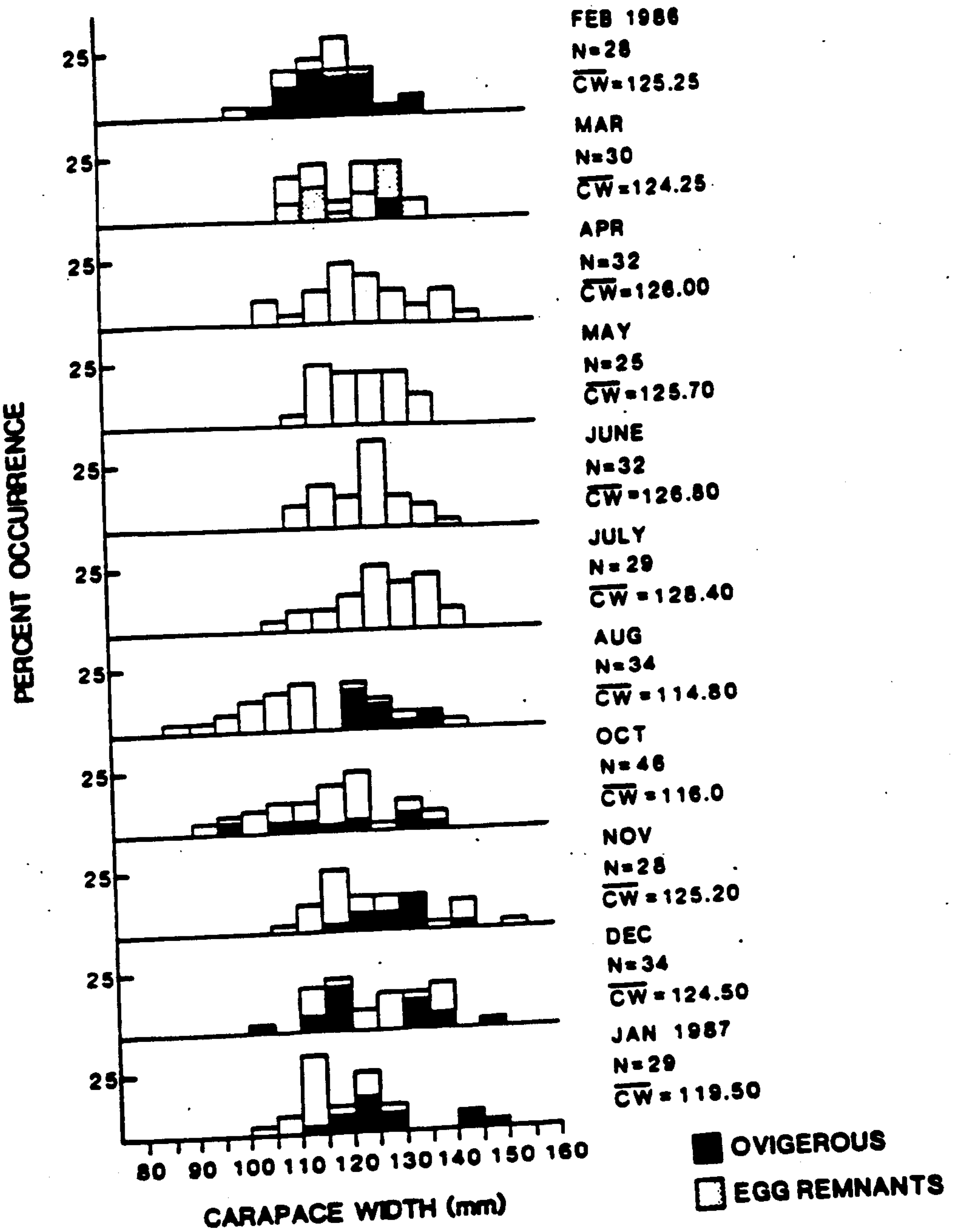


Figure 12. Monthly size frequency distributions of female Chaceon fenneri collected from southeast Florida, including number of individuals (N) and mean carapace width (CW).

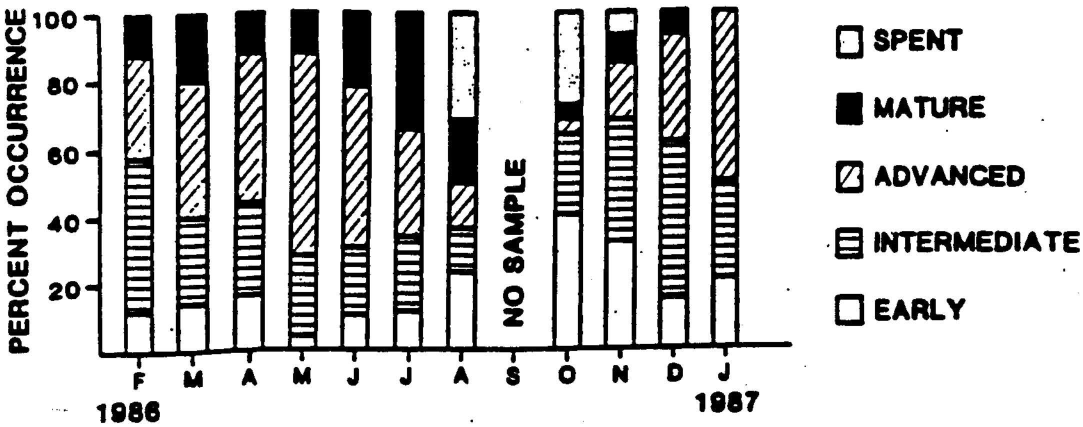


Figure 13. Monthly ovarian stages of Chaceon fenneri collected from southeast Florida. Key to ovarian stages is given in the figure.

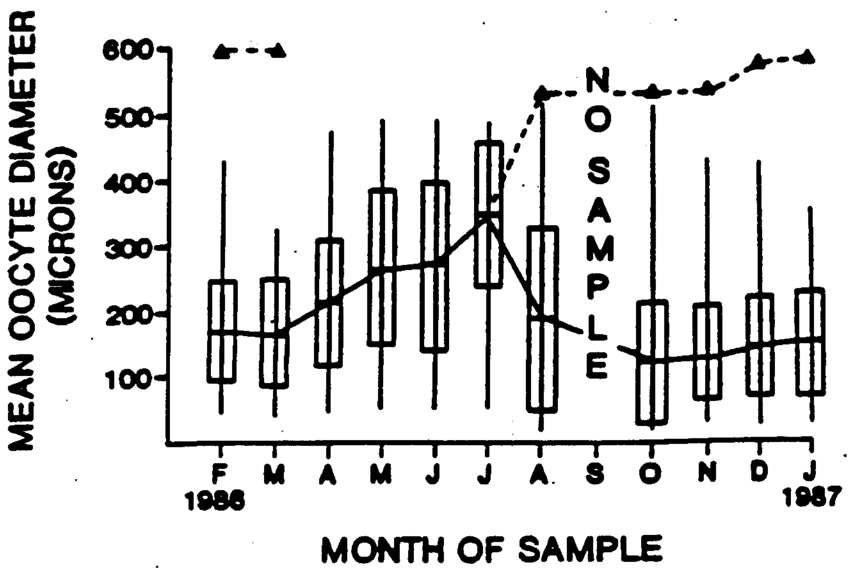


Figure 14. Mean oocyte diameter of Chaceon fenneri by month of sample including standard deviation and oocyte diameter size range. Triangles represent size of extruded eggs.

Mean monthly oocyte diameter gradually increased each month and reached a maximum during July, prior to the initiation of oviposition in August. Mean oocyte diameter of 188.2 µm recorded in August included both mature and spent/redeveloping ovaries."

The reproductive cycle of golden crab was studied in the eastern Gulf of Mexico by Hinsch (1988):

"...females of *Geryon fenneri* were ovigerous from September to March in this study. The presence of some females in early October without egg masses suggests that these had yet to oviposit their eggs, since most had mature purple oocytes within their ovaries. Other ovigerous females at the time had small cream yellow ovaries. The latter contain immature oocytes that have not initiated vitellogenesis and are indicative of ovaries that have recently been spawned. All females collected until February were ovigerous. During February and March, some females released larvae when collected and some contained empty egg cases attached to their pleopods. No female crabs collected during April and May possessed egg masses attached to their pleopods. The reproductive pattern seen in *G. fenneri* suggests that an annual spawning season exists each year.

Changes in the reproductive tract of the male golden crab *Geryon fenneri* paralleled those of the female. The males examined over the period of this study showed progressive changes in the large numbers of follicles containing primary spermatocytes in October-November to large numbers of follicles filled with mature sperm in February-March. The increase in the number of mature sperm in the testes was followed by an increase in the diameter of the regions of the vasa deferentia. This increase initially became apparent in the anterior portion, but ultimately included middle and posterior portions as well. Such changes from September through May suggested a seasonality of reproduction in males of *G. fenneri* as well."

3.1.3.2 Fecundity

The following text and Figures 14 and 15 are from Erdman (1990):

"Mean egg diameter for *C. fenneri* is 540 µm at the time of oviposition. This increases with development to between 580 and 600 µm prior to hatching (Figure 14). Regression analysis of egg number on carapace width is shown in Figure 15. The number of eggs per female increased with increasing carapace width as described by:

Number of Eggs = 4,465.7 CW - 346,105 $r^2 = 0.64$

Thus, the number of eggs extruded is directly correlated with the size of the female. Egg number for the twelve females examined ranged from 131,000 through 347,000."

3.1.3.3 Size at Sexual Maturity

The following text and Figure 16 are from Erdman (1990):

"In addition to the onset of ovarian development and the presence of extruded eggs, other characteristics must also be considered in the assessment of size at sexual maturity in brachyurans. Following the pubertal molt, the abdomen and gonopores show changes that are generally accepted as external morphological indications of sexual maturity and subsequent mating (Hartnoll, 1969).

Chaceon fenneri exhibits the simple pattern of gonopores described by Hartnoll (1967), with three distinct types recognized. Type A gonopores which are narrow and slit-like are present on sexually immature animals. Type B gonopores which follow the pubertal molt are elongate and ovoid in shape, while type C is a modification of type B differing only in that the

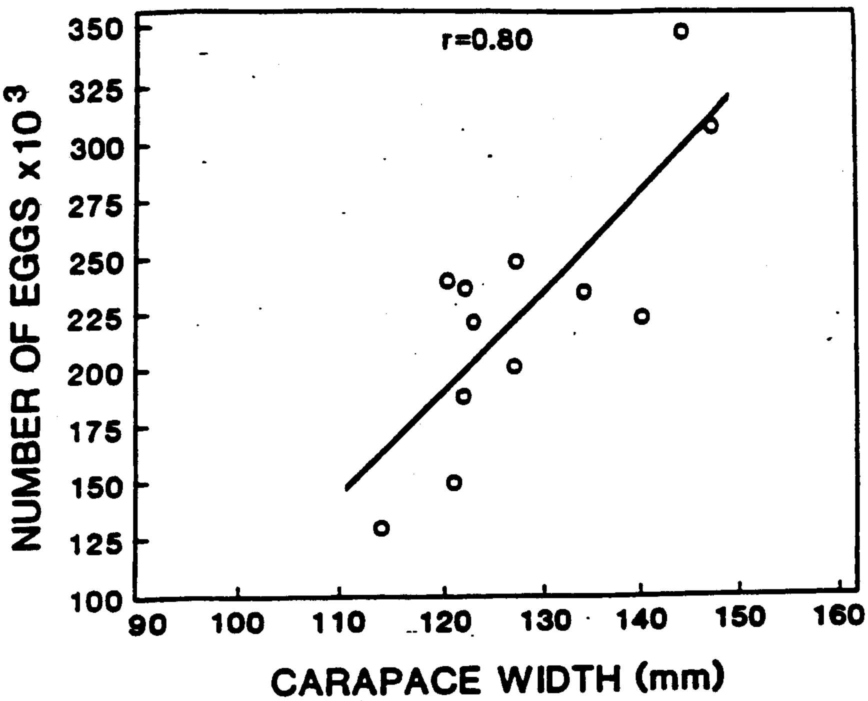


Figure 15. Relationship in Chaceon fenneri of brood size on carapace width as described by: number of eggs = 4,465.7CW - 346,105.

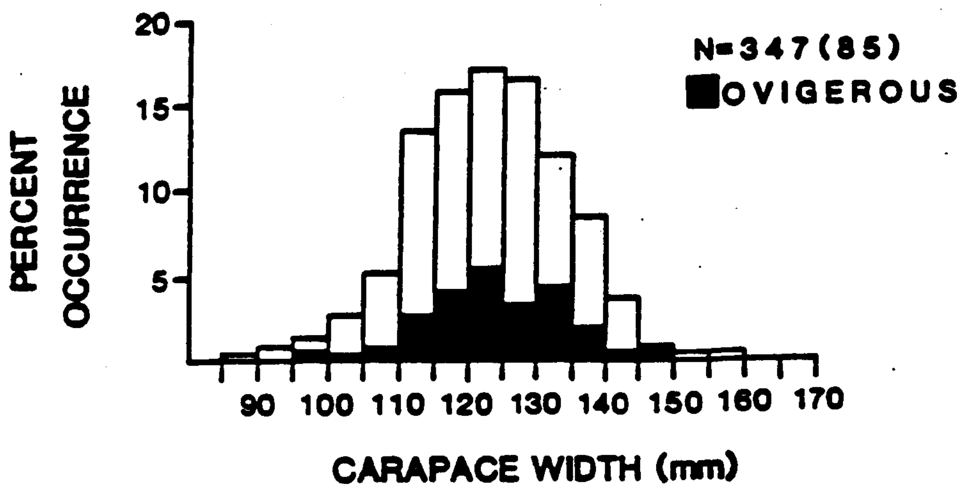


Figure 16. Cumulative size frequency distribution of 347 female Chaceon fenneri collected from southeast Florida. Solid areas indicate ovigerous females.

gonopore is more elongate and gaping as a result of mating during the immediate post-molt period. In addition, type C gonopores often exhibit a blackened margin due to abrasion by the male pleopods during mating.

Carapace width of the 347 females examined ranged from 89 to 156 mm. Eighty-five females were ovigerous (25%) and ranged in size from 97 to 147 mm CW (Figure 16). All ovigerous females examined exhibited type C gonopores (elongate and gaping) with 74% having blackened margins. Type C gonopores were also observed on non-ovigerous females ranging in size from 103 to 156 mm CW, with 60% of the females examined having sperm in the spermetheca. Thus type C gonopores appear indicative of sexual maturity and previous mating. However, non-ovigerous females with type C gonopores and empty spermetheca may have previously undergone mating and oviposition but have yet to molt and mate again.

Twenty-six females ranging in size from 89 to 118 mm CW were observed in the immediate pre-molt stages during August and October. All individuals examined had ovaries in the immature or early developmental stage and had type A gonopores. Recently molted females collected during the period of October through December exhibited signs of recent mating. Seventy-one percent of females ranging in size from 105 to 120 mm CW had type C gonopores. Seven females were examined for spermetheca contents and five had sperm present. The remaining 29% of recently molted females had type B gonopores and empty spermetheca. Ovaries from all recently molted crabs were either in the early or intermediate stage of development.

Considering the size ranges of ovigerous females, the stages of ovarian development, and changes in gonopore structure associated with the pubertal molt, size at sexual maturity of *C. fenneri* is between 85 and 100 mm CW."

Information for the South Atlantic Bight (Wenner et al., 1987) suggest that females may become sexually mature at 97 mm carapace width. In South Africa, the red crab matures at between 7 and 9 years old and 75 to 90 mm carapace width (Melville-Smith, 1987c).

3.1.3.4 Mating

Erdman (1990) observed mating behavior of golden crab held in captivity:

"Mating in Brachyuran crabs may occur immediately following ecdysis by the female (i.e., *Callinectes sapidus*, *Cancer magister*, *Menippe mercenaria*) or may occur when the female is in the intermolt state (i.e. *Grapsus grapsus*, *Maja squinado*, *Pinnotheres maculatus*)(Hartnoll, 1969). Post-molt mating often encompasses complex behavior patterns that include a premolt cradle and post-molt embrace of the female by the male. The embrace is associated with copulation and continues until the female exoskeleton has sufficiently hardened for resumption of normal activities. Conversely, intermolt mating does not exhibit complex courtship patterns and is often of short duration. The contrast in mating patterns has been attributed to differences in gonopore structure (Hartnoll, 1969).

Mating following female ecdysis has been reported in two species of *Chaceon*: *C. longipes* (Mori and Rellini, 1982) and *C. quinquedens* (Elner et al., 1985); however, the mating pattern of *C. fenneri* remains unknown. Although the pattern of mating following molting might be expected to be present throughout the Geryonidae, intra-family differences have been noted in the Xanthidae and Majidae (Hartnoll, 1969).

The following observations are based on two separate episodes of molting and mating of *C. fenneri* held in captivity. Data of this nature when combined with field observations of population structure, reproduction and growth may provide additional insight to the life history of this slope dwelling species. Of particular importance may be the application of these observations to the low frequency of reproduction pattern proposed for *C. fenneri.*

Case 1

Precopulatory behavior was first noted on August 13, when the male formed a protective cage around the female with his walking legs. The male clasped the female by the carapace, dorsal side up, with the first pair of walking legs (2nd periopods). While carrying the female, the male continued to move about on the dactyls of the walking legs and feed at regular intervals. The female was not observed to feed during the premolt embrace. On September 9, the female molted with the male still forming a cage with his walking legs. Unfortunately, the female was unable to back out of the old carapace; hence, mating was unsuccessful.

The soft shell female was dissected to observe the stage of ovarian development. The ovary was slightly swollen and cream in color, an indication of early development. This stage was confirmed through histological examination.

Case 2

On December 10, 1988, the largest male in the aquarium (180 mm CW) formed a cage around the premolt female with his walking legs. The female folded all appendages close to the carapace and was carried dorsal side up beneath the male. The male used the first pair of walking legs (2nd periopods) to grasp the female between the first set of her walking legs (periopods 2 and 3). This carrying behavior continued for 28 days until the female molted. During this period, the male continued to feed at regular intervals and on occasion offered food to the female; however, the female was not observed to feed prior to molting.

Molting began on January 7, 1989. Immediately prior to molting, the male released the female to the substrate and formed a protective cage around her with his walking legs. During this period, the male was observed to repel the two additional males present in the aquarium. The female remained motionless, dorsal side up until the suture at the posterior margin of the carapace was completely open. Typical brachuran molting followed with the female slowly backing out of the old exoskeleton. The male remained in the cage position but did not assist with molting.

Within two hours of the completion of ecdysis, the copulatory embrace began; the pair clasped sternum to sternum with the female inferior, ventral side up. The female was held off the substrate by the male walking legs as previously described. Mating occurred with the extended abdomens of both crabs overlapped and the first pair of male pleopods inserted into corresponding female gonopores.

Following molting and the onset of copulation, the mated pair moved away from the discarded exoskeleton. At this time, the smallest male in the aquarium was observed to cradle and attempt copulation with the discarded exuviae. This peculiar behavior continued for approximately two hours until the male released the exoskeleton; this exoskeleton was removed for remeasurement of premolt morphometrics.

This copulatory embrace continued until February 10, 1989, a duration of 34 days. During this period the male fed actively and was observed to offer food to the female on many occasions. The female was observed to feed on three occasions while still in the copulatory embrace. The male walking legs were not always used to carry the female; often the female was carried by the male pleopods which remained inserted in the gonopores.

The female broke free on February 10, 1989, when the new carapace had hardened sufficiently for increased locomotory activity. Upon examination, the new carapace was brittle and slightly flexible, and bright creamy gold in color. Carapace width was 139 mm, an increase of 13 mm. Gonopores were type 3 with prominent blackened margins from abrasion during copulation. Blackened discoloration was also visible on the merus of the second periopods from abrasion by the male walking legs during the copulatory embrace.

Discussion

Mating of *C. fenneri* in the immediate post-molt stage conforms to one of the two basic Brachyuran mating patterns described by Hartnoll (1969). This pattern of long duration premolt and post-molt mate guarding has also been observed in *C. longipes* (Mori and Rellini, 1982) and *C. quinquedens* (Elner et al., 1985). This behavior has obvious survival benefits in that the soft-shell female is protected from potential predation during a period of great vulnerability. The long duration of the premolt embrace also suggest the presence of a pheromone released by the female to attract potential mate (Ryan, 1967).

Of greater significance is that the second female was sexually mature when collected. Thus, molting of this female which had shown signs of previous reproductive activity suggests multiple mature instars rather than a single mature instar (Melville-Smith, 1987c).

The ovarian condition and gonopore stage of the first molting female infers that if successful, this molt would be the pubertal molt associated with the onset of sexual maturity. The 91 mm premolt carapace width of this individual was well within the proposed carapace width range of 85-100 mm that is the size at sexual maturity in this species. As molting occurred in early September, a period when oviposition occurs in reproductively active females, this individual would be expected to undergo oviposition the following fall. This suggests that sperm may remain viable for up to 12 months in this species. Delayed oviposition following mating has also been reported for *C. quinquedens* (Elner et al., 1985).

The second female was sexually mature when collected and the presence of blackened type 3 gonopores is indicative of pervious mating activity. Of greater significance were the egg remnants on the pleopods which indicate that this female had recently hatched eggs prior to collection in February. This female did not undergo oviposition during the fall moths after collection, yet the December period of molting conformed to molting patterns observed from southeast Florida and the eastern Gulf of Mexico. Thus, the temporal incidence of molting in both females held in captivity was temporally asynchronous to the reproductively active members of the sampled populations, yet showed a degree of synchrony with those members of the populations observed to undergo molting. The alternate pattern of molting and mating provides further evidence for the low frequency of reproduction pattern suggested for this species."

During their study of the South Atlantic Bight (Wenner et al., 1987), a captured female was maintained in an aquarium: "Observations on molting and mating of a female (110 mm CW), which had been held in a refrigerated aquarium since February 1986 and had completed ecdysis in late May 1986, confirmed that female golden crab molt just before mating occurs."

In the eastern Gulf of Mexico, golden crabs appear to mate in the hardened state Hinsch (1988):

"The presence in the females of swollen seminal receptacles filled with seminal fluids and sperm serves as evidence for the time of mating. Female *Geryon fenneri* with immature ovaries contained sperm plugs in their seminal receptacles, suggesting that these might have mated following the molt to maturity. Not all female crabs mate at the time of the molt to maturity. Female crabs of the family Majidae mate initially and thereafter in the hardened condition sometime after the terminal molt (Hartnoll, 1963; Hinsch, 1972). The presence of barnacles and blackened spots on the carapace of many female golden crabs are indicative of a long time since molting, suggesting that female golden crabs can mate in the hardened condition as well. The presence of sperm in the seminal receptacles suggests that the crabs may even be capable of holding sperm from one copulation over for successive seasons. In the spider crab *Libinia emarginata* (see Hinsch, 1972), a single mating may suffice to provide sperm for several broods. Transmolt retention of sperm in the seminal receptacles has been reported in *Menippe mercenaria* (see Cheung, 1968)."

3.1.3.5 Larval Distribution & Recruitment

The following text and Figure 1 are from Lockhart et al. (1990):

"The distribution patterns of *Chaceon fenneri* and possibly *C. quinquedens* in the eastern Gulf of Mexico suggest a causal role for the Loop Current System (Maul 1977) in basic life history adaptations. Female distribution within these species' geographic ranges and the timing of larval release supports this hypothesis. Ours was the first study to discover female golden crabs in any significant numbers and was also the first to find a major population of female red crabs in the Gulf of Mexico. Both of these concentrations of females were seemingly shifted counter-current to the Loop Current circulation. We hypothesize that this counter-current shift is linked to larval release and transport, and serves to maximize recruitment into the parent population by minimizing risk of larval flushing.

Similar counter-current shifts of other female decapods have been reported or hypothesized. In the Gulf of Mexico, spawning female blue crabs (*Callinectes sapidus*) have been hypothesized to undergo a late summer spawning migration in the northeastern Gulf of Mexico that is counter to the Loop Current system (Oesterling and Adams 1979). Female western rock lobsters (*Panulirus cygnus*) are hypothesized to undergo migration to favor recruitment back into the parent population (Phillips et al. 1979). Kelly et al. (1982) proposed that only those red crab larvae (*Chaceon quinquedens*) released up-current in the species' range will recruit back into the parent population. Melville-Smith (1987a, 1987b, 1987c) in a tagging study of red crabs (*C. maritae*) off the coast of southwest Africa, showed that the only segment of the population exhibiting significant directional movement were adult females: 32% of recaptures had moved greater than 100 km and the greatest distance traveled was 380 km over 5 yr. This directional movement was later shown to be counter to the prevailing surface currents (Melville-Smith 1990). Thus, within decapods in general, and the genus in particular, adult females are capable of, and appear to undergo, long-distance directional movement in their lifetimes.

A similar migration of adult female golden crabs, counter-current to Loop Current circulation in the Gulf of Mexico (Fig. 1), would produce the geographic population structure observed off the southeastern United States. Females would be most common farthest up-current whereas males would be most common intermediate in the species geographic range. Wenner et al. (1987) reported a 15:1 (M:F) sex ratio in the South Atlantic Bight and in this study, we had an overall sex ratio of 1:4 — both consistent with hypothesized net female movements to accommodate larval retention and offset the risk of larval flushing.

In fact, given this, two female strategies could maximize recruitment in a prevailing current. The first is for females to position themselves far enough up current so that entrainment would return larvae to the parent population (Sastry 1983). The second is to avoid larval entrainment altogether and thus avoid flushing of the larvae out of the system. Female *Chaceon fenneri*, and perhaps *C. quinquedens*, appear to use both strategies but rely mainly on the latter.

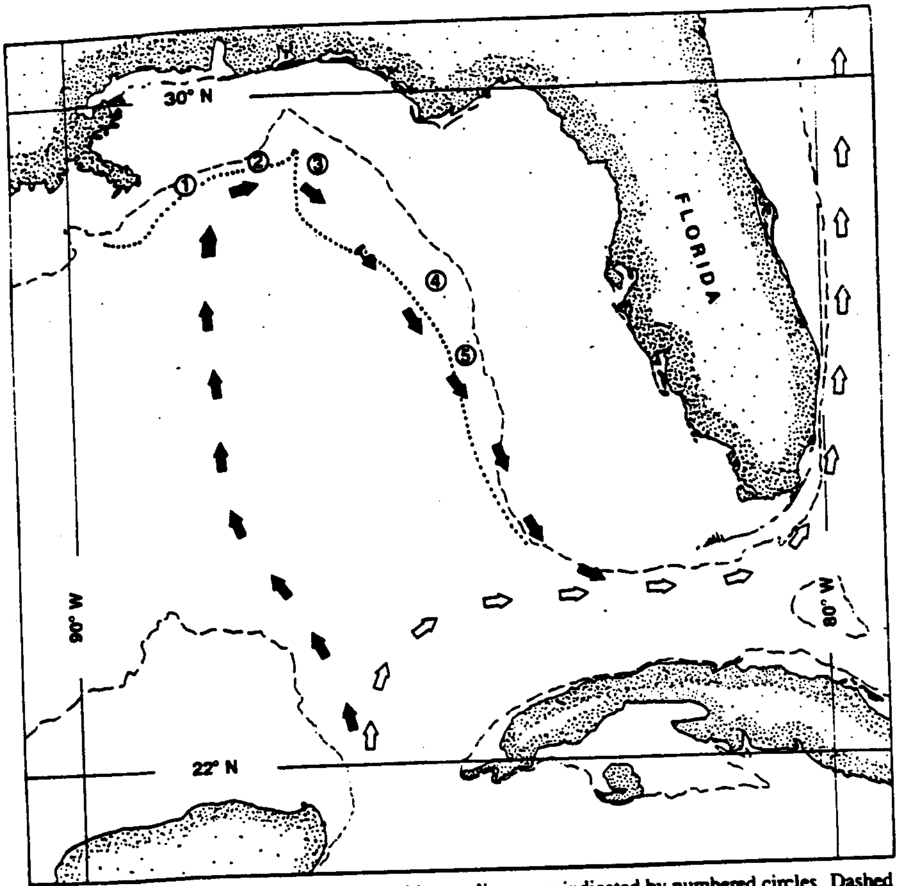


FIG. 1. Map of the eastern Gulf of Mexico with sampling areas indicated by numbered circles. Dashed line shows the 183 m isobath. Dotted line shows the 400 fathom 732 m isobath. Arrows show approximate minimum (open arrows) and maximum (closed arrows) annual penetration of the Gulf Loop Current.

Female golden crabs release larvae offshore in depths usually shallower than 500 m. If larvae were released directly into the Loop Current-Gulf Stream System, they would be entrained for their entire developmental period. Given a developmental time of 33-40 d at 18°C (K. Stuck, Gulf Coast Research Laboratories, Ocean Springs, Mississippi, pers. comm.) and current speeds of 10-20 cm/sec (Sturges and Evans 1983), transport of the larvae would be 285 km to 690 km downstream. Thus, larvae released on the Atlantic side of Florida are in danger of being flushed out of the species' range before recruiting to the benthic stock. Likewise, larvae released directly into the current in the southeastern Gulf of Mexico would be flushed from the Gulf.

Female golden crabs release larvae from February to March (Erdman and Blake 1988; Erdman et al. 1989) and the greatest concentration of female golden crabs to date found in this study was in the northeastern Gulf of Mexico off central Florida. Only during this period and in this region (Maul 1977), can female golden crabs avoid complete entrainment and possible flushing of larvae out of the system. Partial entrainment of larvae might still occur, but its duration should be much reduced, and the risk of larval flushing minimal. This hypothesis predicts that most larvae should be found near the concentrations of females we found in the northeastern Gulf of Mexico with decreasing settlement further downstream. The abundance of juveniles should show a similar pattern.

One need not invoke similar counter-current movements for male geryonid crabs. In particular, males moving perpendicular to adult females (i.e. males moving up and down the continental slope) would have a greater encounter rate with females than males moving along the slope with females. Given low female reproductive frequency (Erdman et al. 1989), intense male-female competition (Lindberg and Lockhart 1988), and probability of multiple broods (Hinsch 1988) from a single protracted copulation (H. M. Perry, pers. obs.), the male strategy should be to intercept relatively rare receptive females all along the species' range, not to aggregate with presumably inseminated females. This hypothesis would predict a relatively uniform abundance of males along their geographic range. In addition, the incidence of inseminated females should be high farthest upstream with an ever decreasing percentage downstream. Our study supports the former hypothesis but we cannot address the latter.

The distributional patterns of geryonid crabs we observed are consistent with those reported from elsewhere. Furthermore, these patterns lead us to suggest that the Loop Current System has had a causal role in life history adaptations of *Chaceon fenneri* and perhaps *C. quinquedens*. In general, females are expected to release larvae during a time and in a region where risk of larval flushing is minimal (Sinclair 1988), whereas males are expected to compete intensely for rare, receptive mates."

The coastal physical oceanography in the Florida Keys was described by Yeung (1991) in a study of lobster recruitment:

"The strong, northward-flowing Florida Current is the part of the Gulf Stream system confined within the Straits of Florida. It continues from the Loop Current in the Gulf of Mexico, and proceeds beyond Cape Hatteras as the North Atlantic Gulf Stream.

The mean axis of the Florida Current is approximately 80 km offshore of Key West and 25 km off Miami (Lee et al. 1991). Mean annual cross-stream surface current speed in the Straits of Florida is approximately 100 cm/s (U.S. Naval Oceanographic Office 1965).

Brooks and Niller (1975) observed a persistent countercurrent near Key West extending from surface to the bottom, and from nearshore to approximately 20 km seaward. They believed that it was part of the cyclonic recalculation of the Florida Current between the Lower and Middle Keys.

The presence of a cold, cyclonic gyre was confirmed by physical oceanographic data collected in the SEFCAR cruises. It was named the Pourtales Gyre since it occurs over the Pourtales Terrace -- that area of the continental shelf off the Lower and Middle Keys (Lee et al. 1991). When the Florida Current moves offshore, the Pourtales Gyre forms over the Pourtales Terrace, and can last for a period of 1-4 weeks.

The Pourtales Gyre could entrain and retain locally spawned planktonic larvae for a short period. The combination of the cyclonic circulation and enhanced surface Ekman transport could also advect foreign arrivals into, and concentrate them at, the coastal boundary (Lee et al. 1991).

Vertical distribution of the larvae within the 3-dimensional circulation will subject them to complicated hydrographic gradients, which might influence their development time, and hence their dispersal potential (Kelly, Sulkin, and van Heukelem 1982; Sulkin and McKeen 1989). Thus, variability in the circulation features and water mass properties can lead to variability in larval transport and recruitment."

The Pourtales Gyre may provide a mechanism for entrainment of golden crab larvae spawned on the Florida east coast, and also as a mechanism to entrain and advect larvae from the Gulf and Caribbean (e.g., Cuba). This possibility is supported by the conclusion of Yeung (1991) suggesting that larvae of a foreign origin supply recruits to the Florida spiny lobster population:

"The foreign supply of pre-recruits arriving with the Florida Current might easily meet the same fate as the locally spawned larvae, that is, passing on with the Florida Current. The Pourtales Gyre may play a significant role in recruitment by providing a physical mechanism to entrain and advect larvae into the coastal boundary.

The Pourtales Gyre, even if linked with the Dry Tortugas gyre or the Florida Bay circulation, may not be able to provide a pathway much more than 2 months in period. For locally spawned *Panulirus* larvae to be retained for their entire development would require several circuits -- not impossible, but unlikely"

The timing of the Pourtales Gyre provides a mechanism for local recruitment of *Scyllarus* larvae (Yeung, 1991) and may also provide a similar mechanism for golden crab larvae. The following figure (Figure 12) is a generalized pathway for lobster larvae (Moe, Jr., 1991). Golden crab larvae from the Gulf of Mexico, Cuba, and possibly other areas of the Caribbean, probably provide larvae to the South Atlantic population. The proportion of local recruitment is unknown but could be significant.

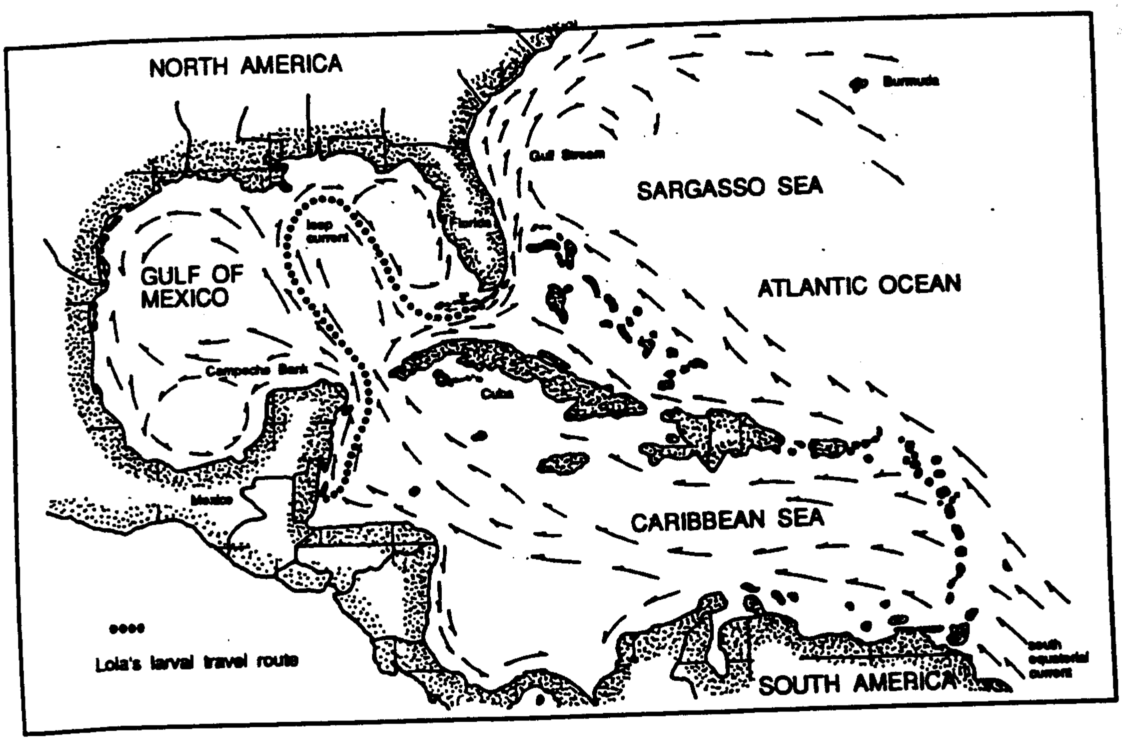


Figure 12. Lola's travel route as a phyllosome larva.

3.1.4 Feeding

Feeding habits are very poorly known. Golden crabs are often categorized as scavengers that feed opportunistically on dead carcasses deposited on the bottom from overlying waters (Hines, 1990).

3.1.5 Movement

Wenner et al. (1987) found in the South Atlantic Bight that: " Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migrations such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al., 1982)."

Lindberg and Lockhart (1993) found in the Gulf of Mexico: " The golden crab *Chaceon fenneri* in the eastern Gulf of Mexico exhibits a typical bathymetric pattern of partial sex zonation and an inverse size-depth relationship, as first reported for red crabs (*C. quinquedens*: Wigley et al., 1975; *C. maritae*: Beyers and Wilke, 1980). Sex segregation, with females shallower than most males, was more evident in our results than in those of Wenner et al. (1987) from the South Atlantic Bight, primarily because our trap catch had a higher proportion of females (25.9% compared to 5.2%)."

3.1.6 Mortality Rates

No mortality information is available for golden crabs. Melville-Smith (1988) studied the red crab off southwest Africa and estimated total mortality from catch curves. Total mortality (Z) for different fishing areas ranged 0.24 to 1.40.

Melville-Smith (1988) stated "With the limited information, there is no way of accurately calculating what portion of Z is made up by natural mortality (M). Also, there is very little comparative information on decapod natural mortality in the literature. Most studies of cold-water crabs and lobsters have used an assumed or roughly calculated low value, 0.1 (Thomas, 1973) and 0.02 (Ennis, 1979) for *Homarus americanus*, 0.1 for *Jasus edwardsii* (Annala, 1980), and 0.14 for *Cancer pagurus* (Bennett, 1979). For warmer water lobsters, M has tended to be quoted as higher, 0.14-0.52 for *Panulirus argus* (Munro, 1974 quoted by Cobb and Wang, 1985) and 0.226 for *Panulirus cygnus* (Morgan, 1977).

G. maritae is slow growing (Melville-Smith in press b) and lives in cold water at temperatures of 4.5-10.4°C (Beyers and Wilke, 1980). Furthermore, size frequency analysis of the catch (Fig.3) reveals that large crabs are abundant in areas where the rate of commercial exploitation is low. These factors suggest that the rate of natural mortality is low. Therefore, calculations involving M in this paper have been made with three values of M, 0.05, 0.10 and 0.15, the true value (which is unlikely to be constant over the whole grounds), probably lying somewhere within that range."

2.3 Catch and Catch Per Unit Effort

The following text is taken directly from Appendix F, page F-2 and F-3 (Harper and Scott, 1998):

"Reported Logbook Golden Crab Catches

Table 1 provides a monthly summary of the information for the 434 Golden Crab Trip Report Logbook forms which reported fishing activity. For the Middle Zone (area between 25° N. latitude and 28° N. latitude), estimated monthly golden crab catches from 330 trips completed furring the entire period, November 1995 through April 1998, were 1.39 million pounds. Over the entire time period Middle Zone monthly catches averaged 46,315 pounds and ranged from 13,600 pounds for November 1995 to 84,872 pounds for May 1997 (Figure 1). Logbook report forms representing 104 trips with golden crab landings made in the Southern Zone (areas south of 25°) between February 1997 and March 1998 were submitted. Southern Zone estimated golden crab catches for these reported trips were 395,275 and averaged 28,234 pounds per month over the fourteen reported months.

Catch-per-unit-effort

The number of trap hauls reported for the 434 trips in the golden crab logbook database was 49,301 (Table 1, Figure 2). During the logbook time period the average number of traps hauled per month was 1,216 in the Middle Zone and 860 in the Southern Zone. Harper (1996) reported that golden crab catch-per-unit-effort as measured by mean catch (pounds) per trap haul was increasing during the period November 1995 through March 1996. With additional trips over a longer time period available for calculations, CPUE trends appear to be exhibiting seasonal patterns with peak CPUE occurring in winter-spring (December through May) with lower CPUE values calculated during summer-fall (June through November). For the Middle Zone, golden crab monthly mean catch per trap haul was 42.8 pounds during winter-spring and 32.7 pounds during summer-fall (Figure 3).

Incidental catch

Incidental catch information was estimated by fishers and reported on the Golden Crab Trip Logbook forms. The most frequently reported incidental catch species was the giant isopod, *Bathynomus giganteus*. A total of 17,455 estimated pounds of giant isopod were caught between November 1995 and April 1998 (Table 2). The overall mean catch per trap haul was 0.36 pounds and ranged from 0.12 pounds during May 1996 to 0.61 pounds during October 1996. In general, reported incidental catch of other species was very low. In addition to the giant isopod, nine other species categories representing a total incidental catch of 26.5 pounds over the period November 1995 through April 1998 were reported on the logbook forms. These species categories and estimated catch were: rockfish - 7.5 pounds, hake - 6.0 pounds, whiting - 3.0 pounds, jonah crab - 2.8 pounds, shrimp - 2.0 pounds, queen snapper - 2.0 pounds, squid - 1.2 pounds, red crab - 1.0 pounds, and scorpion fish - 1.0 pounds."

2.4 Size Frequency Data

The following text is taken directly from Appendix F, page F-4 (Harper and Scott, 1998):

"TIP Sampling

TIP sampling of the golden crab fishery began during May 1995. A total of 51 trips have been sampled and 4,801 golden crabs have been measured through December 1997. Table 3 presents the monthly number of crabs measured and carapace width statistics. The overall mean carapace width of sampled golden crabs was 148.5 mm. (N=4,801, std.=12.6) and ranged from 142.5 mm. (N=475, std.=16.3) during September 1995; to 157.7 mm. (N=161, std.=8.3) during January 1997."

2.5 Stock Status

The following Section 3 information is directly from the Golden Crab Fishery Management Plan (SAFMC, 1995) [Note: Figures are from the Golden Crab FMP]:

"3.1.7 Abundance

Golden crab abundance studies are limited. Data from the South Atlantic Bight (Wenner et al., 1987) estimated abundance from visual assessment was 1.9 crabs per hectare while traps caught between 2 and 10 kg per trap. Wenner and Barans (1990) estimated the golden crab population in small areas of 26-29 square km between 300-500 m off Charleston to be 5,000-6,000 adult crabs. In the eastern Gulf of Mexico adult standing stock was estimated to be 7.8 million golden crabs and the biomass was estimated to be 6.16 million kg (13.6 million pounds) (Lindberg et al., 1989). Experimental trapping off Georgia yielded an average catch of 7 kg per trap (Kendall, 1990).

3.1.8 Present Condition

Unknown due to lack of data.

Sea Grant (Florida and South Carolina) hosted a research workshop on Geryonid Crabs and Associated Continental Slope Fauna in January 1989 (Lindberg and Wenner, 1990). The Rapporteur's comments (taken directly from Armstrong, 1990) on crab management and the east coast United States Geryonid fisheries provides useful insight into the potential for a golden crab fishery:

1. In general, participants at the conference were not overly optimistic about the prospects for large and sustained fisheries for these species because of their deep water distribution, evidence of infrequent recruitment, slow growth, older age at reproductive and legal size, and fairly low density over extended regions of the species' range.
2. Crab management was reviewed and as in the case of most crab fisheries, much of the management is directed toward providing safeguards for reproductive effort by excluding females from the fisheries and setting minimum sizes to allow for adequate male reproduction before capture by the fisheries (Table 1).
3. Fisheries prospects for golden crab in the South Atlantic Bight to the Gulf of Mexico are more tenuous than for the red crab fishery in the northeast United States. Golden crabs seem to be distributed at very low densities but have the capacity to locate food and traps over an apparently great distance (Wenner, 1990; Wenner et al., 1987) which portends rapid depletion in areas heavily fished. Given aspects of both species' life history (Hines, 1990) such as deep water distribution at cold temperatures, slow growth and relatively advanced age at maturity and legal size, it seems that high sustained yield is not likely. As in the case of other crab fisheries listed in Table 1, managers could take a conservative approach (as apparently has been done) that allows capture only of males of a size and age beyond reproductive maturity, with the objective of maintaining species reproductive effort quite apart from the knowledge of biotic and abiotic factors that affect year class strength.

Species	Sex Fished	Size Limit (mm carapace width)	Estimated Minimum Age in Fishery (YR)	Season Closure	Pre-Season Survey	Gear	Range of Landings (over last 15 yrs) (lb x 10^6)	Quota	Comment
Red King Crab[1] (*Paralithodes camtschatica*)	M	165	8-10	Yes	Extensive	Pot	3-130 Bering Sea	"harvest range" guidelines	
Tanner Crab[2] (*Chionoectes bairdi*)	M	140	6-8	Yes	Extensive	Pot	47-146 all Alaska	"harvest range" guidelines	
Dungeness Crab[3] (*Cancer magister*)	M	165	3-5	Yes	Virtually None	Pot	16-60 Cal-Alaska plus British Columbia	None	Pre-season survey for male shell condition only
Blue Crab[4] (*Callinectes sapidus*)	M, F	75-125	2	Yes; variable between states	No	Pot, dredge, trawl, trotlines	40-104 Chesapeake Bay	None	
Stone Crab[5] (*Menippe mercenaria*)	M, F	claws only, propodus >70	2-3	Yes	No	wooden trap	0.5-3.0 Florida	None	
Red Crab[6] (*Chaceon maritae*)	M, F	None gear 100% selective for crab >75mm	6-8	No	No	Pot	7.7-13.1 SW Africa	None	Japanese fishery off SW Africa; age of catch estimated to be between 8-16 yrs. of age
Golden Crab[7] (*Chaceon fenneri*)	M, F	None	?	No	No	Pot	?	None	

[1]Otto 1986; NPFMC 1988
[2]Otto 1981; NMFS Fisheries stats 1983-88, Alaska Sea Grant 1982
[3]Alaska Sea Grant 1985; PMFC 1987
[4]Millikin and Williams 1984; Jamieson 1986; Cronin 1987
[5]Ehrhardt and Restrepo 1989
[6]Melville-Smith 1988
[7]Workshop Participants

Table 1. Representative crab fisheries and comparison of major features of management and landings.

4. In order to provide some likelihood of reasonable annual catch by participating fishermen, managers may want to consider a limited entry fishery as has been done with a number of Australian invertebrate species. Given the expense of capitalization for such deep water fishing, it seems that fishermen are vulnerable to the vagaries of surplus male abundance which could be quickly reduced by unrestricted participation. Without an annual preseason survey and resultant catch quota at the present, there is no basis to attenuate excessive annual exploitation and spread capture of large males over several years, particularly if year classes reaching legal size are infrequently strong as hypothesized for *P. camtschatica* in the Bering Sea. Limited entry (and effort) might achieve this goal of more stable yield, although somewhat blindly since state fisheries agencies will likely not conduct surveys to estimate stock abundance as a means to index the degree of annual exploitation by a limited entry fishery.

5. Another option as practiced for some west coast Canadian invertebrate fisheries that are not well studied and regulated is that of "boom and bust". So long as rudimentary guidelines safeguard reproductive effort, the fishery is allowed to grow to any size (unrestricted vessel participation) and achieve 100% exploitation as it is able. Eventual decrease in abundance and reduction in landings are a consequence to which fishermen must adjust as they either stay with golden crab or move to other fisheries.

3.1.9 Maximum Sustainable Yield

Information to calculate maximum sustainable yield (MSY) is extremely limited. Ideally, one would like to have catch and effort data for 10 years, information on size and age of the catch, fishery independent data, and information relating spawning to recruitment. If these types of data were available for golden crab, surplus production models, spawner/recruit models, and catch-at-age models (e.g., virtual population analysis) could be used to conduct a stock assessment. Faced with such a severe lack of data, the Council had no choice but to use a more simple approach relating the fishing mortality rate to the rate that would produce the maximum sustainable yield.

This is not necessarily all bad as described by Hilborn and Walters (1992: 4):

"A management authority can go about the difficult business of making choices among quantitative alternatives in three ways. First, it may simply mimic choices made under similar circumstances by other authorities under the assumption that previous decision making has already involved careful evaluation of alternatives. Second, it may make an initial choice that 'looks reasonable' on intuitive grounds, then plan to systematically vary the choice while monitoring biological and economic responses, so as to eventually find the best choice by an empirical process of trial and error. Third, it may engage in formal stock assessment, the construction of quantitative models to make the best predictions possible about alternative choices based on whatever data are available to date, and then base its choices on the models while expecting to refine or modify the choices later as more data become available. A combination of the second and third approaches, using a mixture of quantitative modelling and empirical management experimentation, has come to be called 'adaptive management' (Walters and Hilborn 1976, Walters 1986)."

The following discussion concerning MSY based on natural mortality is from an examination of reference points (RPs) for fishery management with application to straddling and highly migratory resources (FAO, 1993). The FAO document was prepared to offer technical input on practical options for management of these resources. Straddling resources includes species which occur within the jurisdiction of multiple countries and for which management should be coordinated. As such, the theory and approach is useful for golden crab which are known to occur in the U.S., Bahamas, and Cuba. In addition, the information presented below is generic to any species as it relates basic principles of population dynamics.

"New fisheries usually develop in the absence of adequate assessment information, and management has to proceed on the basis of information available at that point in time. It is important that the rate of fishing during the early stages does not exceed the rate of learning (e.g. Hilborn and Sibert 1988). A more cautious approach may result in underexploitation, but this will not necessarily lead to a loss of potential yield (see later sections on Risk). In the 1960-70s, many new fisheries developed in different parts of the world, for which the only data on stock status was one or several estimates of biomass from exploratory fishing campaigns or fishery surveys. In an attempt to provide some basis for fleet and fishery development, a simple empirical formula for the MSY was proposed by Gulland (1973) in terms of the virgin biomass B_0 and the natural mortality rate M, notably MSY = 0.5 M B_0. (A reformulation of the second yield equation in Annex I), and follows the symmetrical Schaefer yield model in assuming that MSY will occur at half the virgin stock size B_0, and that at MSY, the fishing mortality and natural mortality rates will be equal. Later, a more cautious approach was used, and Gulland generalized the equation to
MSY = x.M.B_0 with the value of x being related to the stock characteristics. Garcia et al. (1989) proposed several estimators for MSY when historical data series are not available.

There is in fact little empirical evidence that F_{MSY} = M for a majority of stocks. Beddington and Cooke (1983) suggested that x is generally smaller than 0.5, while for tropical penaeids Garcia and Lereste (1981) suggested that values x = 0.32 to 0.44 are appropriate. From a limited set of 11 stocks, Caddy and Csirke (1983) found values were bounded by x = 0.33 to at least x = 4, the lowest values being shown by short-lived shrimp and a sardine populations, and the highest by two northern demersal finfish; apical predators with low natural mortality rates. From an analysis of a series of small pelagic stocks, Patterson (1992) found that only low exploitation rates (no more than 40%) corresponding to not more than x = 0.33 are sustainable. The point of mentioning these very approximate benchmarks is that for many straddling stocks off developing coastal countries, setting 'Precautionary' RPs might still have to draw upon such procedures."

Because of the lack of both fishery-dependent and fishery-independent data from the golden crab fishery, it has not been possible to develop a MSY estimate for the golden crab fishery in the south Atlantic. A preliminary analysis was prepared with the assistance of Dr. John Merriner, NMFS SEFSC Beaufort Lab.

Preliminary MSY Analysis

Mortality estimates are available from work on the red crab off southwest Africa (Melville-Smith, 1988): Natural mortality (M) range = 0.05, 0.10, and 0.15 (see Section 3.1.6 Mortality Rates).

The biomass (B_0) of golden crab in the south Atlantic is unknown. An estimate of adult golden crab biomass for the eastern Gulf of Mexico is available (Lindberg et al., 1989). Based on research from the eastern Gulf of Mexico, adult biomass was estimated to be 13.6 million pounds (see Section 3.1.7 Abundance).

The quantity of habitat suitable to golden crab in the south Atlantic is unknown. For purposes of the preliminary MSY analysis, habitat in the south Atlantic was assumed to be equal to and two times the quantity of habitat in the eastern Gulf of Mexico.

Finally, the sex ratio was assumed to be either 1M:1F or 2M:1F. This recognizes results of research which show a higher proportion of females in the south Atlantic.

Using these estimates, maximum sustainable yield can be calculated (Table 2) using the formula:

$$MSY = 0.5\ M\ B_0$$

Table 2. Maximum sustainable yield based on estimated abundance of golden crab in the Gulf of Mexico.

Natural Mortality (M)	Total Biomass Pounds	SATL Habitat = GM MSY Sex ratio 1M:1F	SATL Habitat = GM MSY Sex ratio 2M:1F	SATL Habitat twice GM MSY Sex ratio 1M:1F	SATL Habitat twice GM MSY Sex ratio 2M:1F
0.05	13,600,000	170,000	227,800	340,000	455,600
0.10	13,600,000	340,000	455,600	680,000	911,200
0.15	13,600,000	510,000	683,400	1,020,000	1,366,800

Based on the preliminary analysis, maximum sustainable yield was estimated to range between 170,000 and 1,366,800 pounds. This information was included in the September 1995 draft fishery management plan which was reviewed by the public, attendees at public hearings, the Council's Golden Crab Advisory Panel, the Council's Scientific and Statistical Committee, and the South Atlantic Council.

<u>SC DNR Analysis</u>

In addition to the preliminary analysis, the Council requested Dr. Elizabeth Wenner, Mr. Glenn Ulrich, and Dr. Charles Barans from the South Carolina Department of Natural Resources examine their data from the South Atlantic Bight and provide an estimate of MSY for golden crab in the south Atlantic. The analysis provided was reviewed by the Council's Scientific and Statistical Committee, the Golden Crab Advisory Panel, and the Council. This information was also distributed to members of the public prior to the final public hearing during the October 1995 Council meeting. The complete analysis as outlined in a letter from Dr. Elizabeth L. Wenner, Mr. Glenn F. Ulrich, and Dr. Charles Barans, which was FAXED on October 11, 1995 is as follows:

"The following information is provided for use of the South Atlantic Fishery Management Council in determining standing stock estimates and MSY for *Chaceon fenneri* (golden crab). Since neither the true density of crabs nor their habitat distributions are known for the entire South Atlantic Bight from Cape Hatteras to Cape Canaveral or beyond, standing stock can be estimated in several ways to obtain a range of values that might be considered conservative or liberal. We are providing estimates based on an expansion of in situ crab densities from a relatively small geographic and bathymetric area to develop our first estimate. A second approach is based on trap catches and effective fishing area (EFA) within the most productive areas surveyed in 1985-86.

In the first estimate, the surface area of ocean bottom of golden crab (*Chaceon fenneri*) distribution was estimated from a NOAA, National Ocean Survey series of detailed bathymetric maps (transverse mercator projections) with depths contoured at 50 m intervals. Using each of the map sheets necessary between Cape Canaveral (28°30'N) and Cape Fear (34°00'N), the depth contours for 350 m and 550 m were located and visually approximated as straight lines (1 cm = 2.5 km). These depth contours were chosen because they contain most of the trapping effort, greatest catches of golden crab, and visual observations from a submersible. Flat surface area from the chart was calculated for the resulting triangular and trapezoidal figures representing areas between the 350-550 m depths. Areas (km^2) were summed throughout the region. Using this method, a total bottom area estimated from flat map surface was 19,517.7 km^2.

From submersible observations, a density of 1.9 crabs/ha (190 crabs/km^2 averaged over several habitat types) was found by Wenner and Barans (1990) for depths of 300-600 m. Expanding to the area from Cape Canaveral-Cape Fear, an estimated number of 3.7 million crabs is obtained. This estimate is dependent on the assumption that unbiased visual observations of crabs were made from a submersible and that these density estimates are applicable to the entire area under consideration.

Based on a sex ratio of 22M:1F (3039 males, 135 females from traps; Wenner et al. 1987) for depths of 300-600 m, the standing stock of males is 3,541,124 and that of females 166,876. Assuming an average weight of 927 g (2.04 lbs) per male crab in depths of 274-549 m (Wenner et al. 1987), the total biomass of males is 7,223,893 lbs.

Using Gulland's formula, MSY = 0.5 M B_0, where MSY is maximum sustainable yield in kg, M is the instantaneous rate of natural mortality based on a range of values determined for *C. maritae* (Melville-Smith In press), and B_0 is the estimated total biomass of males, the following estimates of MSY from the first method are derived:

M	B_0 (in millions)	MSY (millions of lbs.)
0.05	7.2	0.18
0.10	7.2	0.36
0.15	7.2	0.54

In the second population estimate, EFA of traps (3625m^2) was calculated using the observed crab density in some of the more productive habitats from first year submersible work (0.8 crabs/1000 m^2) in conjunction with mean crab catch (2.9 crabs/trap, from 274-549 m) collected concurrently in the same areas. This assumes that EFA is the same for all geographic and depth areas where it has been applied.

The linear distance from due east of Charleston, SC to Cape Canaveral, FL along the 150 fathom (275 m) contour is 518.6 km and the average width of each 50 fathom stratum in the area where our sampling occurred was 3.7 km. An assumption that this is the average width of these depth strata for more productive areas throughout the region was made.

Depths 274 - 366 m: Area = 518.6 km x 3.7 km = 1918.8 km^2.
Depths 367 - 457 m: Area = 518.6 km x 7.4 km = 3837.6 km^2.

Total golden crabs taken in year 1 & 2 for each depth zone were divided by total number of traps set to yield the following:

274 - 366 m: 162 crabs in 59 traps = 2.7 crabs/trap.
367 - 549 m: 4147 crabs in 446 traps = 9.3 crabs/trap.

For depths 274-366, a density estimate and standing stock estimate was obtained as follows:

$\frac{2.7 \text{ crabs/trap}}{.003625 \text{ km}^2\text{/trap}}$ = 744.8 crabs/km^2.

744.8 crabs/km^2 x 1918.8 km^2 = 1,429,122 crabs
1,429,122 crabs x 0.956(% males) = 1,366,241 male crabs
1,366,241 x 0.927 kg/crab = B_0 of 1,266,505 kg or 2,786,311 lbs.

M	B_0 lbs.	MSY lbs.
0.05	2,786,311	69,658
0.10	2,786,311	139,316
0.15	2,786,311	208,973

For depths of 367-549 m, a density estimate and standing stock estimate was obtained as follows:

$\frac{9.3 \text{ crabs/trap}}{.003625 \text{ km}^2\text{/trap}}$ = 2565.5 crabs/km^2.

2565.5 crabs/km^2 x 3837.6 km^2 = 9,845,363 crabs
9,845,363 crabs x 0.956 (% males) = 9,412,167 male crabs
9,412,167 x 0.927 kg/crab = B_0 of 8,725,079 kg or 19,195,174 lbs.

M	B_0 lbs.	MSY lbs.
0.05	19,195,174	479,879
0.10	19,195,174	959,759
0.15	19,195,174	1,439,638

Total MSY estimates for Method 2:

M	274-366 m	367-549 m	Total lbs.
0.05	69,658	479,879	549,537
0.10	139,316	959,759	1,099,075
0.15	208,973	1,439,638	1,648,611

In addition to the population estimates presented here, substantial areas on the Blake Plateau may support significant numbers of crabs although a very limited number of trap sets in these areas indicates that the density is lower than in the shallower strata. In the 400-500 fathom area between 30 and 31°N, 87 traps caught 63 crabs; a mean of 0.7 crabs/trap. Additionally, in these sets males made up only about 40% of the catch.

Golden crabs also occur in the 100-150 fathom stratum and may be abundant in certain areas or at certain times. Drew Kendall of GAMAREX has reported good catch rates in these depths during some of their survey efforts. This data should be examined to determine if it can be utilized to expand the population estimates to these depths.

We hope that you will find this information useful in management proposals for golden crab. Differences in estimates of MSY between methods reflect choices of crab densities and habitat area variables for calculations. Should you need any clarification or additional information about these estimates, please give us a call."

Table 2. Summary of MSY estimates.

Preliminary Estimate	MSY	=	170,000	to	1,366,800 pounds
SCDNR Method #1*	MSY	=	180,000	to	540,000 pounds
SCDNR Method #2*	MSY	=	550,000	to	1,650,000 pounds

*For the area Cape Hatteras, NC to Cape Canaveral, FL only.

The Council's Scientific and Statistical Committee reviewed the preliminary estimate and the two SC DNR estimates of MSY and were requested to address the following questions (Memorandum to SSC from Gregg Waugh dated 10/12/95):

1. What is the best available estimate of MSY for the Cape Canaveral, Florida to Cape Fear, North Carolina area?
2. What is the best available estimate of MSY for the Cape Canaveral, Florida area south? This is the area where virtually 100% of the 600,000 pounds caught thus far in 1995 have originated.
3. What are your recommendations about including a numerical estimate of MSY in the document at this time? What about a numerical estimate for the Cape Canaveral to Cape Fear area only and no numerical estimate for the entire fishery?

The SSC discussed the MSY methodology, the source of the distribution and abundance data, the need for adaptive management, and the concern that golden crabs could be easily overfished. There was concern expressed that there was not sufficient data to calculate MSY. SSC members stated that they are not speaking negatively of the information collected and complimented the researchers on their work; however, members concluded there was insufficient information upon which to calculate MSY at this time. The following motions was approved: "The SSC recommends that the Council not present current estimates of MSY in the document because we question the scientific soundness of these estimates." Their intent is that data be collected and an estimate of MSY be calculated as soon as sufficient information becomes available.

The Council's Golden Crab Advisory Panel reviewed the information concerning MSY and concluded there was not sufficient information available to estimate MSY at this time.

The NMFS SEFSC reviewed the preliminary estimate of MSY contained in the September 1995 public hearing document and concluded: "It should be emphasized that this MSY is a very rough estimate which needs to be monitored and modified as more information on the fishery becomes available." "MSY estimates on pages 40-41 (Note: referring to the September 1995 draft FMP document) are based on published data from the Gulf of Mexico and range from 0.17 to 1.37 million pounds depending upon the assumed sex ratio, comparative stock sizes, and assumed mortality rates. There is no scientific basis for the choice of 'best point estimate of 1.4 million pounds,' (also see page 90, Option 4) (Note: referring to the September 1995 document). There is no explanation as to how this choice was arrived at. SCMRRI scientists are evaluating their research data in an attempt to provide B_0 and MSY estimates for a large portion of the U.S. South Atlantic area. Upon review of their data and the process for data expansion by Council staff, SSC, SEFSC, etc. those values may replace the estimate in Table 2, page 41 (Note: referring to the September 1995 document). It is encouraged that population estimates for the Atlantic coast area be used in the MSY calculations. Please note that sex ratios for the South Atlantic collections were quite high for males, 15:1, p.33) (Note: referring to the September 1995 document)."

The South Atlantic Council reviewed the MSY estimates, the methodology, review comments by the NMFS SEFSC, SSC, and Golden Crab AP and concluded, based upon the best available information, not to specify a total MSY for the golden crab resource within the Council's area of jurisdiction. The Council did however conclude there is sufficient information to use in making a very preliminary estimate of potential yield for the area Cape Canaveral, Florida through Cape Fear, North Carolina. The real shortcoming of the available data is the lack of any estimate for the area south of Cape Canaveral, Florida where the majority of the fishery takes place. Therefore, no estimate of MSY is specified at this time. The data collection measures specified in the management plan will generate data useful for calculating MSY. In fact, the Council requested, and NMFS has implemented, a voluntary logbook program beginning in November 1995 to start the data collection process. As soon as sufficient information becomes available to calculate MSY, the framework procedure will be used to incorporate the MSY figures into the management plan.

3.1.10 Probable Future Condition

Golden crabs are a long-lived, slow growing, deep water (cold environment) species. Their reproductive biology is likely to result in periodic recruitment and their abundance in the South Atlantic Council's area is unknown. These life history characteristics suggest conservative management to prevent overfishing.

The rapid development already exhibited by this fishery is expected to accelerate in the immediate future. Southeastern fishermen continue to seek diversification opportunities to alleviate problems experienced in fisheries for traditional species, such as user group conflicts, declining resources and over-capitalization. The net ban in the State of Florida, extensive closures in New England, and large reductions in crab fisheries in the northwest could result in significant influxes of effort into the golden crab fishery. The number of vessels thought to be actively fishing increased from two vessels in January 1995 to about 37 vessels fishing as of August 1, 1995. However, data from the State of Florida and discussions with fishermen, indicate up to 80 individuals have documented landings as of April 7, 1995. An additional 33 individuals would qualify by September 1, 1995 based on data from Florida and discussions with fishermen.

Without management the golden crab resource will become rapidly overfished. This is not a species that can withstand the high fishing mortality from a fleet as large as is likely to enter the fishery."

The following is taken directly from Appendix F (Harper and Scott, 1998):

"Preliminary Production Model Analysis

Catch and estimated effort data for the period 1986-present were fit with a non-equilibrium production model (Prager 1993) to estimate stock status relative to MSY levels. Golden crab quarterly catch in pounds for the South Atlantic region were obtained from the Accumulated Landings System for the period 1986 through October 1996. After October 1996, golden crab catch was derived from the Golden Crab Trip Report Logbook. Quarterly effort levels were estimated by dividing quarterly catch by observed CPUE (lbs per trap haul). CPUE data for 1986 were available in Erdman (1990). CPUE for the most recent period (1996-1998) were from the Golden Crab logbook reports described earlier. The production model was fit to both quarterly and annual data. However, only 3 paired annual observations of catch and effort were available, making the annual model fit of questionable value. Results of the annual and quarterly model fits depended on assumptions made about the initial biomass level. Quarterly catch and estimated effort data are provided in Table 4. For this preliminary analysis, the fishing year was defined to begin in February; thus, the first quarter of the fishing year ended in April and the last quarter ended in January. For this analysis, a total of 49 quarters of catch (February 1986 - April 1998) and 14 quarters of effort were available.

The data were first fit assuming that stock biomass was at model carrying capacity (K=2Bmsy) in January 1986. A total of 501 bootstrap fits of the model to the 14 paired catch and effort observations (Table 4) were used to estimate uncertainty in the model parameters of interest. As the model was fit to quarterly data, estimates of annual parameters, such as MSY, can be obtained by multiplying the parameters of concern by 4. From this model, current biomass is estimated to be at about that level which could produce MSY and the median estimate of annual MSY is on the order of 847,000 lbs per year (approximate 80% CI, ~650,000 - 920,000 lbs per year). The results of this fit are shown in Table 5. Recent (quarterly) fishing mortality rates were estimated to range from about 0.5 to 2 times that needed to achieve quarterly MSY. The estimated time-trajectory of relative (quarterly) biomass and relative (quarterly) fishing mortality rate are shown in Figure 5.

An alternative model was fit to the data in which initial biomass was not fixed at K, but estimated. As above, a total of 501 bootstrap fits of this model to the 14 paired catch and effort observations (Table 4) were used to characterize the uncertainty in parameter estimates. From this model, initial biomass (January 1986) was estimated to be more than twice carrying capacity, current biomass was estimated to be about 50% above that level which could produce MSY and recent fishing mortality rates ranged from about 0.25 to about 1.0 Fmsy. From this model, the estimate of annual MSY is less precisely estimated although the median estimate is on the order of 1,070,000 lbs per year). The results of this fit are shown in Table 6. The estimated time-trajectory of relative (quarterly) biomass and relative (quarterly) fishing mortality rate are shown in Figure 6."

3.0 FISHERY EVALUATION

3.1 Economic Status of The Fishery

This section describes economic aspects of the commercial fishery for golden crab in the South Atlantic region. The Golden Crab Fishery Management Plan went into effect beginning on August 27, 1996 and established three golden crab fishing zones. The northern zone is defined as the EEZ north of 28 degrees N. latitude. The Middle Zone is contained within the EEZ between 25 degrees North and 28 degrees North latitude. The Southern zone extends South from 25 degrees North latitude within the South Atlantic Council's EEZ. Federal permits are issued for a specific zone and fishing is allowed only in that zone for which the permit is issued.

In the South Atlantic region 35 vessels were granted permits to operate in this fishery: 27 permits were issued for the southern zone; 6 permits were issued for the middle zone; and 2 permits were granted to vessels for the northern zone. Other management regulations imposed by the golden crab FMP include: dealer and vessel permitting and reporting; limitations on the size of vessels; prescribing allowable gear (including escape gaps and escape panels); and prohibiting possession of female crabs (see the FMP for a complete list of measures).

The Golden Crab Log book data are summarized in Table 1. The number of trap hauls reported for the 434 reported trips were 49,301, and the average number of trap hauls per month was 1,216 in the middle zone and 860 in the Southern zone. There is some evidence that golden crab catch per unit effort (CPUE) measured as pounds per trap haul varies by season with peak CPUE during the period December to May (Appendix F).

Table 1: Number of Trips, and Landings of Golden Crab in the South Atlantic Region (Appendix F).

Time Period	Zone	Number of Trips	Total Landings	Average monthly Catch
November 1995 - April 1998	Middle Zone	330	1,390,000	46,315
February 1997 - March 1998	Southern Zone	104	395,275	28,234

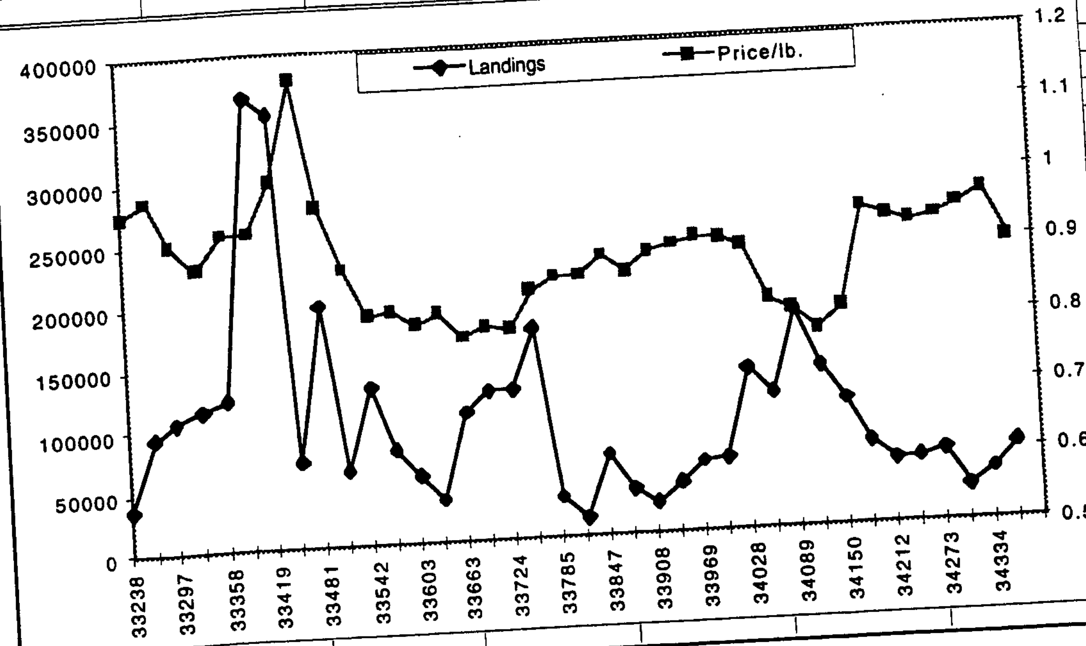
Monthly golden crab landings show a cyclical pattern with the greatest landings between March and July (Figure 1) when the Keys' lobster fishermen enter the fishery. During the period June 1996 to May 1997 the total landings amounted to 897,000 at a total ex-vessel value of $781,000. These landings were down 46% from the previous year's harvest (June 1996 to May 1996).

Of the 35 vessels that were issued permits only about 11 have fished for golden crabs since qualifying (Appendix G). In 1997, Antozzi (1997) reported that only five or six vessels were dedicated to harvesting this species full time. One vessel docked in St. Petersburg, one in Ft. Lauderdale, two in Marathon Key, and one or two in the lower Keys. Seasonally about a dozen vessels fish for golden crab during the closed lobster season, March to July.

An update for 1998 indicated that only 1 vessel was operating in this fishery full time, and there was no production in the Gulf of Mexico. In addition, the expected boost in landings that occurred in previous summers was not observed during the summer of 1998. This is due to the fact that spiny lobster fishermen who participate in this fishery from March to July chose to pursue other fisheries or did not fish during this season.

An important issue may be ex-vessel prices which is an important determinant of entry and exit behavior in any fishery. For golden crab, ex-vessel price declined from $0.90 and $1.04

Figure 1:	Monthly Ex Vessel Golden Crab Landings (pounds) and Nominal Price
	Data Taken from Vondruska (1998)



per pound in 1995 to $0.83 in 1997. This decline in 1997 is particularly noticeable considering that harvest was at higher levels in 1995 (Figure 1). Dockside prices reported in early 1998 were between 75 and 80 cents per pound. This price decrease is likely due to the increased supply of other large crabs, especially snow crab.

This product is viewed in the marketplace as a substitute for snow crab clusters. Most of the product is processed into clusters, which is not as favored as other large crab species such as snow crabs. The golden crab market is strongly influenced by the wholesale market for snow crabs (Antozzi, 1998). A large proportion of the Alaskan catch of snow crab goes to Japan and the drop in the yen reduced the export demand for this product. The excess supply entered the domestic market and lowered snow crab prices, which may be partly responsible for depressed golden crab prices. The increase in production from Russia and Canada also magnified this problem.

Antozzi (1997) concluded that the market for golden crab is inhibited from expanding due to a supply constraint. He attributes this lack of production to the difficulty and cost of operating in this fishery, which requires a sizable investment in specialized gear including on-board holding facilities that keep crabs alive. This fishery takes place in deep water and this can result in lengthy trips under adverse sea conditions. Some industry members have stated that vessels larger than 50 feet are needed to cope with rough sea conditions offshore and to provide the stability needed for trap deployment and retrieval.

The future outlook for this market will be strongly influenced by the market supply of other large crabs, and the health of export markets. The outlook on this market would improve if this product could be viewed as more than just a substitute for snow crabs. Steady production and other product forms such as picked meat were suggested as ways to overcome this problem. However, Antozzi (1998) was of the opinion that this fall off in price may not reverse unless the Japanese economy improves.

3.2 Social Evaluation - South Atlantic Fishing Communities as Defined in the Sustainable Fisheries Act Amendment (SAFMC, 1998a)

"4.3.3 Fishing Communities - Identify and define fishing communities

Identifying fishing communities provides a basis for analyzing impacts of management measures on fishing communities rather than on a fishery-wide basis. This would be more relevant in situations where impacts are differential because of the location, level of activity and dependency on fishing, availability of alternative job opportunities, etc. in different fishing communities. This measure would allow fishery managers to obtain information on the impacts of future management measures on different fishing communities. It could make for the formulation of management measures that would minimize impacts on fishing communities that have less opportunities to adapt to changes imposed by the measures.

Identification and definition of fishing communities would normally have a positive impact, except that, for the South Atlantic, there are no data collected on fishing communities. National Standard 8 imposes requirements on the council and the fishery management regulatory process that cannot be satisfied given existing data. Current data available do not allow for a meaningful definition of fishing community, moreover, do not provide a measure of dependence upon fishing and will not contribute to useful impact analysis.

At its March meeting, the Gulf of Mexico Fishery Management Council's Socio-economic Panel recommended that further research be initiated and funded by National Marine Fisheries Service as soon as possible to aid in the identification and definition of fishing communities in the Southeast. The panel also recommended the scope of this problem be addressed at a national level, such that impacts upon fishing communities can be analyzed across regions as well as within. A key area for expanded research is ethnographic and survey research to identify, not only communities, but those who provide supporting services to the economy and culture of fishing communities. Especially important in the Southeast is the need to provide a realistic portrayal of recreational fishing, diving, and eco-tourism and their importance to a fishing community.

The Council concluded incorporating all available information at this time will meet the mandates of the recent Magnuson-Stevens Act amendments relative to fishing communities.

With the addition of National Standard 8, FMPs must now identify and consider the impacts upon fishing communities to assure their sustainable participation and minimize adverse economic impacts [MSFCMA section 301 (a) (8)].

The proposed guidelines for this new standard state: *"...fishing communities are considered geographic areas encompassing a specific locale where residents are dependent on fishery resources or are engaged in the harvesting or processing of those resources. The geographic area is not necessarily limited to the boundaries of a particular city or town. No minimum size for a community is specified, and the degree to which the community is 'substantially engaged in' or 'substantially dependent on' the fishery resources must be defined within the context of the geographical area of the FMP. Those residents in the area engaged in the fisheries include not only those actively working in the harvesting or processing sectors, but also ``fishery-support services or industries," such as boat yards, ice suppliers, or tackle shops, and other fishery-dependent industries, such as ecotourism, marine education, and recreational diving."* [Federal Register Volume 62, Number 149 (August 4, 1997)]

"The term 'sustained participation' does not mandate maintenance of any particular level or distribution of participation in one or more fisheries or fishing activities. Changes are inevitable in fisheries, whether they relate to species targeted, gear utilized, or the mix of seasonal fisheries during the year. This standard implies the maintenance of continued access to

fishery resources in general by the community. As a result, national standard 8 does not ensure that fishermen would be able to continue to use a particular gear type, to target a particular species, or to fish during a particular time of the year." [Federal Register Volume 62, Number 149 (August 4, 1997)]

"The term 'fishing community' means a community that is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew, and fish processors that are based in such communities. A fishing community is a social or economic group whose members reside in a specific location and share a common dependency on commercial, recreational, or subsistence fishing or on directly related fisheries-dependent services and industries (for example, boatyards, ice suppliers, tackle shops)." [Federal Register Volume 62, Number 149 (August 4, 1997)]

In order to determine a community's "substantial dependence" or "sustained participation" on fishing, those communities must first be identified. Presently, the NMFS has not identified fishing communities, nor their dependence upon fishing in the South Atlantic. Moreover, there are no ongoing data collection programs to gather the necessary information that would allow for the identification of fishing communities in the South Atlantic or other regions. Also, there are no future plans to implement any such data collection program that would determine dependence upon fishing in order to provide the Councils with important information necessary for social and economic impact analysis of fishing communities. This leaves the councils with existing data collected through other agencies, not always specific to fisheries management, i.e., census data, regional economic census, and previous research on specific fisheries. Although this data can be useful, it is often not specific enough to identify or provide a clear representation of a community and its dependence upon fishing. One reason for this difficulty is that fishermen in a specific fishery often do not reside within one particular municipality that can easily be identified as a fishing community or one that is substantially dependent upon fishing. Also, that information is often not provided at the municipality level, but more often at the county level.

Commercial fishermen may have a domicile (home) in one community and dock their boat in another. They may sell their fish in either place or an entirely different location. Recreational fishermen often do not live on the coast, but drive from inland counties and may launch their boats or fish from several different sites. For these reasons, identifying a "fishing community" becomes problematic in that such a community does not fit the normal geographic boundaries or fall within the metes and bounds that would surround a normal incorporated municipality.

The impacts of fisheries management may be minimal in a single community, but, when taken overall may be substantial to an entire county or several county area. Those same measures may have a small impact on a large metropolitan area, but, to a neighborhood where most fishing families live or most fishing activity originates it could be substantial. Therefore, a "fishing community" may encompass a single municipality, a county, several counties or one neighborhood within a major metropolitan area depending upon a variety of demographic, social, economic and ecological factors that one must consider.

One important circumstance to consider when assessing the impacts upon fishing communities is the difference between rural and urban areas, as many fishing communities exist in rural areas on the Southeast coast. There are several ways in which rural areas differ from the more urban or metropolitan as illustrated in *Understanding Rural America* (ERS-USDA, 1993).

Rural areas have consistently lagged behind urban areas with respect to real earnings per job and education levels. Rural areas have also seen a rise in subgroups who are prone to economic disadvantage--families headed by single mothers and minorities. However, these differences vary across the country and are influenced by several factors, one of which is the availability of natural resources. In order to explain and examine some of these differences, counties within the U.S. have been classified as either metropolitan or non-metropolitan. A further subdivision of non-metro counties provides a more clear understanding into each subtype's dependence upon certain economic specialization and the importance of those differences to the residents of those counties (ERS-USDA, 1993). The following classification system may also suggest a possible method for defining an area's dependence upon fishing using the appropriate criteria.

Six types of non-metro counties have been classified, three of which are based upon economic specialization - farming, manufacturing and services. The other three county classifications are based upon their relevance to policy -- retirement-destination; Federal lands; and persistent poverty. Using earned income as a measure of dependence, the classification for counties based upon economic specialization is as follows:

Farming counties - 20% or more earned income from farming
Manufacturing - 30% or more earned income from manufacturing
Services - 50% or more earned income from services industries

Those counties whose classification is based upon economic specialization are mutually exclusive; the other three classification types are not mutually exclusive (ERS-USDA, 1993).

This type of classification system, based upon a percentage of earned income or other measure, might be used to determine a community, county or region's dependence upon fishing. However, like farming counties, those dependent upon fishing have likely seen a decline in the dependence upon fishing over time. This is probably due to significant increases in the population of coastal areas since the 1970's. Much of the population growth has been in the form of immigration of people 60 and older who seek coastal areas for retirement destinations. The increase in this population sector, in turn, brings a greater dependence upon service industries. Choosing such a measure of dependence is not possible at this time and would have to be developed through further analysis and/or research.

Griffith and Dyer developed a typology of fishing community dependence for the Northeast Multi-species Groundfish Fishery (MGF) (Aguirre, 1996). In that typology, they identified critical indicators of dependence which included specific physical-cultural and general social-geographic indicators, i.e., number of repair/supply facilities; number of fish dealers/processors; presence of religious art/architecture dedicated to fishing; presence of secular art/architecture dedcicated to fishing; number of MGF permits; and number of MGF vessels. Using previous results and supplemental research of their own, they were able to develop a fishery dependence index score for the five primary ports in the MGF.

From their research Griffith and Dyer were able to document five variables which best predicted dependence upon the MGF:

1. Relative isolation or integration of fishers into alternative economic sectors, including political participation. To what extent have the fleets involved in the MGF enclaved themselves from other parts of the local political economy or other fisheries? How much have the MGF fleets become, similar to an ethnic enclave, closed communities?

2. Vessel types within the port's fishery. Is there a predominance of large vessels or small vessels, or a mix of small, medium, and large?

3. Degree of specialization. To what extent do fishers move among different fisheries? Clearly, those fishers who would have difficulty moving into alternative fisheries or modifying their vessels with alternative gears are more dependent on the MGF than those who have histories of moving among several fisheries in an opportunistic fashion.

4. Percentage of population involved in fishery or fishery-related industries. Those communities where between five and ten percent of the population are directly employed in MGF fishing or fishing-related industries are more dependent on the MGF than those where fewer than five percent are so employed.

5. Competition and conflict within the port, between different components of the MGF. Extensive competition and conflict between fishers within the same port--as well as between different actors in the MGF, such as boat owners and captains--seem to be associated with intensive fishing effort and consequent high levels of dependence on the MGF. In this case, dependence may have a strong perceptual dimension, with fishers perceiving the resources they are harvesting to be scarce and that one fleet's gain is another fleet's loss.

It is important to understand that these factors are appropriate for the MGF and are not necessarily the best predictors for all fishing communities. Fisheries in the Southeast will differ markedly from those in other regions of the country, especially with regard to their integration into other economies and notably the tourist economy. Recreational fishing is an integral part of the tourism and service economy that has developed for coastal communities in the South Atlantic. For these communities, dependence upon fishing will undoubtedly be tied to commercial and recreational fishing and their associated businesses. Therefore, it is important for fishery dependence models to be developed specifically for the South Atlantic.

Griffith and Dyer (Aguirre 1996) also discuss their description of fishing communities as it relates to the term Natural Resource Community (NRC). Dyer et. al define a NRC as "a population of individuals living within a bounded area whose primary cultural existence is based upon the utilization of renewable natural resources" (1992:106). Natural Resource Communities possess an elementary connection between biological cycles within the physical environment and socio-economic interactions within the community. An adaptation to working on the water by fishermen has important implications for the community as a whole because of the necessary support activities that take place on land, i.e., net hanging & mending; fish handling & preparation; boat building & repair. This important tie to the physical environment not only dictates occupational participation, but structures community interaction and defines social values for those living in Natural Resource Communities. While fishing communities in the MGF are not bounded or set apart from the larger community in which they reside, they still manifest certain recognizable features that would classify them as NRCs (Aguirre 1996). Fishing communities in the South Atlantic will also show signs of being integrated into the larger economy, but may still maintain certain vestiges of an NRC. Fishermen in the South Atlantic, like those in the Northeast MGF, will not likely see their ecological systems being closed, but affected by a host of other forces, both globally and locally. Far more detailed research will need to be conducted among South Atlantic fishing communities to determine changes in integration of the larger economy. One of the most likely changes will be an increasing dependence upon the service sectors as recreational fishing and other recreational activities play an increasing role in the economies of coastal communities. While there will continue to be a connection between the social and physical environments, the nature of that interaction will undoubtedly change.

At this time there is insufficient data to completely identify and define fishing communities in the South Atlantic. The following description of fishing communities provides information to explore ways of defining fishing communities that range from geographical regions to a well bounded municipality. With varied levels of research or data available for each state, descriptions of fishing communities will depend upon the amount of data available and the specific nature and timeliness of that data. In some cases, it may be possible to find a municipality that will clearly fit a definition of fishing community and meet a criterion for dependence upon fishing. In others, it may be a series of communities or counties designated a "fishing community" or possibly a particular sector of a large metropolitan area.

Readily available data will be discussed to allow for public input on the best way to identify fishing communities and determine their dependence upon fishing. Following the discussion of fishing communities in the South Atlantic a discussion of data needs and format will provide possible directions for data collection and analysis. The Council welcomes comments on all aspects of incorporating this new national standard, in order to devise a classification system which will assist in assessing the impacts of fishery management upon fishing communities.

4.3.3.1.1 South Atlantic Fishing Communities

According to NMFS, South Atlantic commercial fishermen have harvested well over 250,000 pounds of seafood in each of the years 1995 and 1996 (Table 1). Those landings have represented over $200,000,000 in harvest value. The value of those landings can become even greater once it diffuses throughout South Atlantic fishing communities as it provides employment and other benefits to other sectors within each community's economic base.

Table 1. U.S. Domestic Commercial Fishing Landings by Region, 1995 and 1996.
Source Fisheries of the United States, 1996

	1995		1996	
Region	**Thousand pounds**	**Thousand dollars**	**Thousand pounds**	**Thousand dollars**
New England	592,665	580,957	641,821	564,169
Middle Atlantic	240,413	179,747	241,936	181,869
Chesapeake	845,632	174,229	728,830	158,736
South Atlantic	**277,035**	**238,112**	**268,990**	**209,407**
Gulf of Mexico	1,464,718	724,619	1,496,875	680,304

Commercial seafood landings also represent other forms of expenditure which have an impact upon fishing communities, such as: fuel, gear, groceries, etc. Support industries like, gas stations, tackle shops, grocery stores all have an investment in the harvesting capability of the local fishing fleet.

As with commercial fishing, recreational fishing activity will also contribute to the economic base of a fishing community as fishermen buy fuel, bait, tackle and food & beverage for fishing trips. Figure 1 demonstrates an increasing trend in recreational fishing trips for most

South Atlantic states, but, also substantial variation in the number of trips over time. Such variation can mean significant economic impacts for those communities that rely upon recreational fishing.

South Atlantic fishing communities will depend upon both recreational fishing and commercial fishing for determining the importance of fishing to their economic base. The supporting role of associated businesses will also need to be incorporated into any measure of dependence. Such businesses as: seafood dealers and processors, marinas, gas stations, bait and tackle shops, dive shops, trucking firms, restaurants and many others, all have some role in determining dependence upon fishing. Unfortunately, data that is robust and/or specific enough does not exist to include in such a determination.

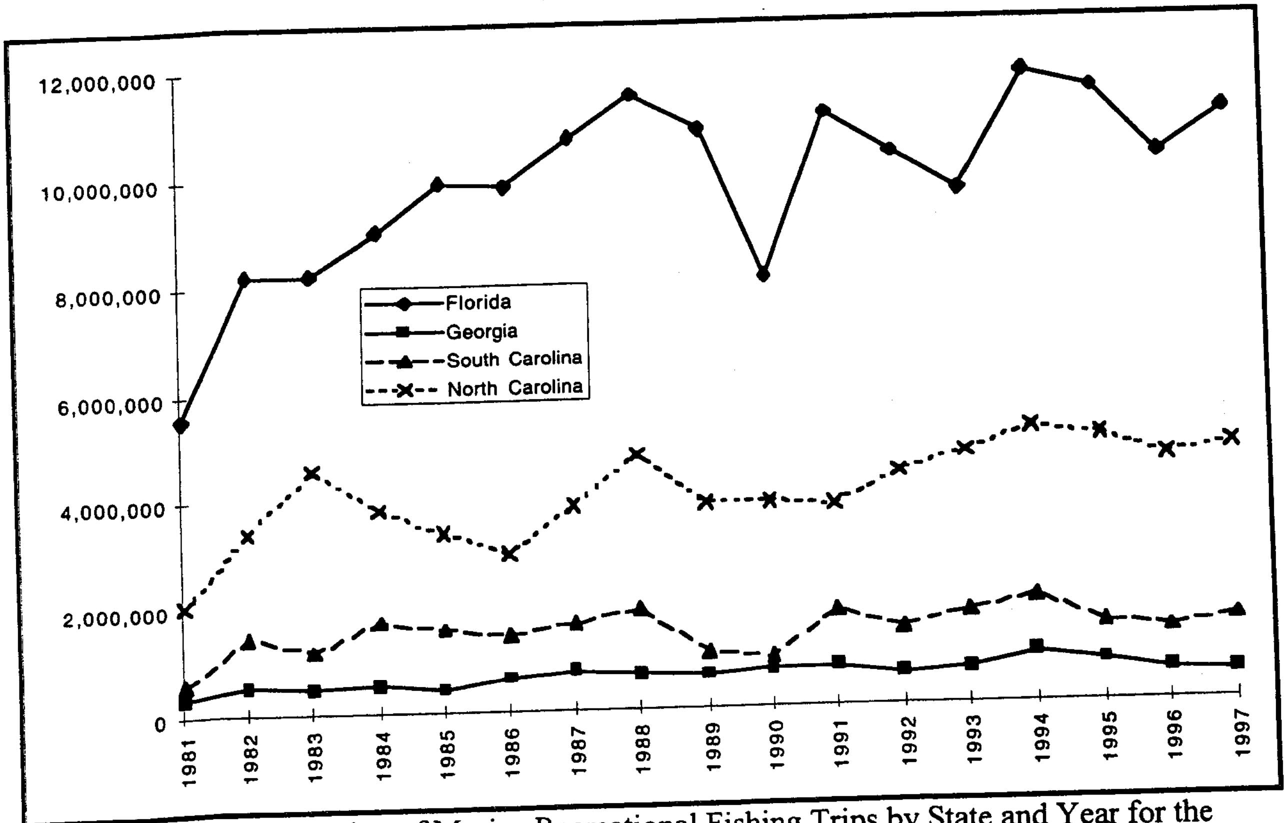


Figure 1. Estimated Number of Marine Recreational Fishing Trips by State and Year for the South Atlantic. Source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division.

To identify fishing communities in the South Atlantic one might begin with the National Oceanic and Atmospheric Administrations publication *Fisheries of the United States* (1996). Among the various statistics listed are commercial landings of major U.S. ports. These ports could be considered to be substantially dependent upon fishing. Table 2 lists the major ports for the South Atlantic in 1996 and 1995 for quantity and value of landings. Some ports are listed as individual communities while others are a combination of several communities over a limited geographical range. This characterization may be useful as we attempt to further delineate fishing communities in each state. Other sources of information helpful in defining fishing communities include the United States Census and Bureau of Economic Research, which include economic information for many areas of the U.S.

Table 2. Quantity, Value and Rank of Commercial Landings for South Atlantic Ports among Major U.S. Ports Source: Fisheries of the United States, 1996.

Port	1995 Quantity*	1995 Rank	1995 Value*	1995 Rank	1996 Quantity*	1996 Rank	1996 Value*	1996 Rank
Key West	23.4	32	66.7	5	23.7	37	62.8	4
Beaufort-Morehead City, NC	87.0	16	35.0	15	75.4	18	20.3	34
Wanchese-Stumpy Point, NC	39.0	25	25.0	24	43.4	24	24.6	27
Charleston-Mt.Pleasant, SC	11.0	58	19.0	32	---	--	---	--
Cape Canaveral, FL	10.1	--	16.9	35	21.2	43	17.7	42
Darien-Bellville, GA	---	--	11.0	50	---	--	---	--
Beaufort, SC	---	--	11.0	51	---	--	---	--
Englehard-Swanquarter, NC	11.0	58	---	--	15.0	50	---	--
Oriental-Vandemere, NC	9.0	--	10.0	--	14.0	53	13.3	50
Bellhaven-Washington, NC	---	--	6.0	--	---	--	11.5	58

*Value and quantity are in millions of dollars and pounds respectively.

4.3.3.1.2 North Carolina

The 1990 Census of Population and Housing provides the following information for North Carolina regarding individuals who reported their occupation as fisher in Table 3. This data will likely include those individuals who commercially fish fresh water areas and others who are not impacted by fisheries management of marine fisheries at the council level. This information does provide data for comparison and could help set parameters for a measure of dependency upon fishing. It is not recommended that these figures be used to determine dependency upon fishing, however. The 1990 Census classifies year-round full-time workers as all persons 16 years old and over who usually worked 35 hours or more per week for 50 to 52 weeks in 1989.

Table 3. Number of Fishers and Mean Annual Income for North Carolina in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	989	1,271	2,260
Female	47	105	152
Total	1,036	1,376	2,412
Mean Annual Income ($)			
Male	16,315	13,069	14,489
Female	11,518	4,489	6,662
Total	16,097	12,414	13,996

The 1990 Census also provides the following information for North Carolina regarding individuals who reported their occupation as captain of a fishing vessel in Table 4. It is interesting to note that there were no females listed as captain of fishing vessels. This concurs with the much of the research on the occupation of fishing which finds very few women in this role. Although women often play an important role in the fishing operation, they are rarely in the position of captain of fishing vessels.

Table 4. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for North Carolina in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	102	141	243
Female	0	0	0
Total	102	141	243
Mean Annual Income ($)			
Male	26,917	33,640	30,818
Female	0	0	0
Total	26,917	33,640	30,818

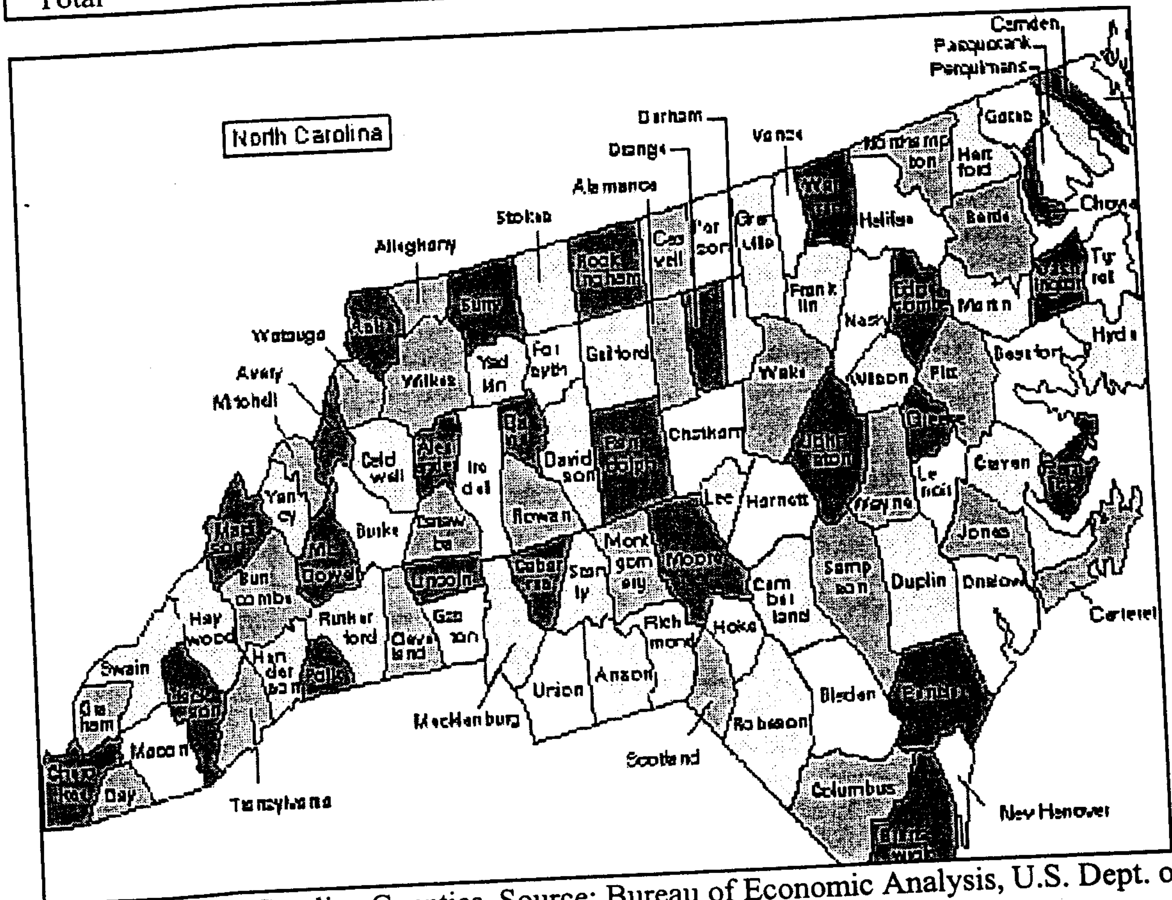


Figure 2. North Carolina Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Johnson and Orbach (1996) have divided North Carolina into six areas for their research on effort management of North Carolina commercial fisheries. Those areas were determined to be distinct with regard to species/gear combinations in addition to sociological, ecological and environmental differences. The areas defined are as follows:

Area 1: Albermarle Area - Currituck, Camden, Pasquotank, Perquimans, Chowan, Bertie, Washington, and Tyrell Counties.

Area 2: Dare County

Area 3: Southern Area - Brunswick, Pender, New Hanover, and Onslow Counties

Area 4: Pamlico Area - Craven, Pamlico, Beaufort, and Hyde Counties.

Area 5: Carteret County
Area 6: Inland Counties.

Area 1: Albermarle Area

The Albermarle area includes the following counties: Currituck, Camden, Pasquotank, Perquimans, Chowan, Bertie, Washington and Tyrell. Johnson and Orbach (1997) found that commercial fishermen in this area had two primary gear types, pots and gill nets. They also concluded that fishermen here move in and out of gill netting on an annual basis.

Table 5. Population and Economic Information for Counties included in Area 1. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 1-County		1993	1994	1995
Bertie	Population	20,631	20,665	20,745
	Personal Income (Thousands of $)	291,226	303,292	328,227
	Per Capita Pers Income ($)	14,116	14,677	15,822
	Personal Income Fishing (Thousands of $)	71	75	84
Camden	Population	6,211	6,370	6,399
	Personal Income (Thousands of $)	92,875	100,012	105,636
	Per Capita Pers Income ($)	14,953	15,700	16,508
	Personal Income Fishing (Thousands of $)	0	0	0
Chowan	Population	13,815	13,909	13,958
	Personal Income (Thousands of $)	226,563	234,453	247,428
	Per Capita Pers Income ($)	16,400	16,856	17,727
	Personal Income Fishing (Thousands of $)	128	134	151
Currituck	Population	15,215	15,831	16,285
	Personal Income (Thousands of $)	251,885	269,871	291,055
	Per Capita Pers Income ($)	16,555	17,047	17,873
	Personal Income Fishing (Thousands of $)	358	376	423
Pasquotank	Population	33,220	33,488	33,759
	Personal Income (Thousands of $)	510,623	534,860	574,433
	Per Capita Pers Income ($)	15,371	15,972	17,016
	Personal Income Fishing (Thousands of $)	----	----	----
Perquimans	Population	10,644	10,692	10,737
	Personal Income (Thousands of $)	148,365	162,627	160,912
	Per Capita Pers Income ($)	13,939	15,210	14,987
	Personal Income Fishing (Thousands of $)	----	0	----
Tyrell	Population	3,918	3,875	3,846
	Personal Income (Thousands of $)	56,056	58,138	52,738
	Per Capita Pers Income ($)	14,307	15,003	13,712
	Personal Income Fishing (Thousands of $)	476	500	562
Washington	Population	14,136	14,276	14,138
	Personal Income (Thousands of $)	220,429	229,038	238,124
	Per Capita Pers Income ($)	15,593	16,044	16,843
	Personal Income Fishing (Thousands of $)	225	236	266

Using multidimensional scaling, Johnson and Orbach were able to examine the spatial relationship of various types of fishing in each area. For Area 1, crab potting was the most central fishery. In other words most fishermen in the area do some crab potting. Referring to cliques, they found that for this area fishermen who peeler pot, eel pot, crab pot and gill net flounder differ from those that long haul. Fishermen that long haul will crab pot and gill net flounder but do not engage in peeler pots or eel pots.

In examining the categories which would include fishermen for Area 1 (Table 6) there seems to be no trend regarding either those in Farm/Fish/Forest occupations or the Agriculture, Fishing, Mining Industries. There are both increases and decreases in the number of those within each categories from 1970 to 1990 which varies by county.

Table 6. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 1 for 1970, 1980, and 1990 Census.
Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Bertie County	Farm/Fish/Forest	923	1035	839
	Agri.,Fishing,Mining	1050	1038	884
Camden County	Farm/Fish/Forest	203	220	114
	Agri.,Fishing,Mining	220	181	137
Chatham County	Farm/Fish/Forest	740	904	832
	Agri.,Fishing,Mining	927	934	1286
Currituck County	Farm/Fish/Forest	194	247	316
	Agri.,Fishing,Mining	215	296	309
Pasquotank County	Farm/Fish/Forest	444	491	469
	Agri.,Fishing,Mining	552	478	508
Perquimans County	Farm/Fish/Forest	417	513	299
	Agri.,Fishing,Mining	445	524	316
Tyrrell County	Farm/Fish/Forest	197	249	208
	Agri.,Fishing,Mining	225	273	233
Washington County	Farm/Fish/Forest	408	511	551
	Agri.,Fishing,Mining	462	557	526

Area 2 : Dare County

Within Dare county the following communities have been described through recent research of the snapper grouper fishery and might be considered fishing communities: Manns Harbor, Manteo, Wanchese, Hatteras, Stumpy Point (Iverson 1997). Johnson and Orbach (1997) found that commercial fishermen in this area had two primary gear types, pots and gill nets. In their analysis of fishery networks for Area 2 they again found crab pots to be central. Another interesting difference revealed was that fishermen who shrimp trawl in this area will gillnet for sharks but do not engage in crab potting.

Dare County shows a higher personal income from fishing over the three years listed (Table 7) than most other coastal counties in North Carolina.

Table 7. Population and Economic Information for Counties included in Area 2. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 2 County		1993	1994	1995
Dare				
	Population	24,300	25,106	26,074
	Personal Income (Thousands of $)	429,564	465,011	502,474
	Per Capita Pers Income ($)	17,678	18,522	19,271
	Personal Income Fishing (Thousands of $)	5,426	5,688	6,392

Dare County (Table 8) shows a general increase in the number of individuals in the listed occupations and industries over the twenty years from 1970 to 1990.

Table 8. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Dare County (Area 2) for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Dare County	Farm/Fish/Forest	11	376	637
	Agri.,Fishing,Mining	181	446	655

Snapper Grouper Fishing

Most of the snapper grouper permit holders in Area 2 work out of Hatteras and only a small portion of their annual commercial fishing activity is devoted to targeting snapper grouper species. Black sea bass, snowy grouper, and blueline tilefish are the most frequently targeted species by commercial snapper grouper fishermen from this area. Surface longlining for tuna and swordfish is apparently the most productive and profitable style of commercial fishing in the area, and the small towns of Manteo and Wanchese serve as refuge for a large number of both local and non-local longlining boats (Iverson, 1997).

Area 3: Southern Area

The Southern Area includes the following counties and communities (in parenthesis): Brunswick (Southport). Pender, New Hanover, Onslow (Sneads Ferry). Johnson and Orbach (1997) found that commercial fishermen in this area had four primary gear types: hook-and-line, gill net, hand harvest of shellfish, and trawling. Pot fishing was classified as secondary gear but they report that increasing usage over time could possibly make it a primary gear. It is interesting to note that they also reported that pot fishing showed an increase in all five areas over time. Area 3 showed much more complexity in annual rounds of fishing than Areas 1 or 2 with shrimp trawling, hand clamming and crab potting all central to the network (Johnson and Orbach 1997).

Table 9. Population and Economic Information for Counties included in Area 3. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 3		1993	1994	1995
County				
Brunswick				
	Population	56,350	58,386	60,697
	Personal Income (Thousands of $)	878,453	941,247	1,024,954
	Per Capita Pers Income ($)	15,589	16,121	16,886
	Personal Income Fishing (Thousands of $)	1,595	1,674	1,885
Pender				
	Population	32,554	33,894	33;759
	Personal Income (Thousands of $)	510,623	534,860	574,433
	Per Capita Pers Income ($)	15,681	16,341	17,253
	Personal Income Fishing (Thousands of $)	----	----	----
New Hanover				
	Population	131,091	135,317	139,906
	Personal Income (Thousands of $)	2,620,539	2,800,024	3,036,665
	Per Capita Pers Income ($)	19,990	20,692	21,705
	Personal Income Fishing (Thousands of $)	----	----	693
Onslow				
	Population	145,638	144,951	144,259
	Personal Income (Thousands of $)	1,962,312	2,030,075	2,149,074
	Per Capita Pers Income ($)	13,474	14,005	14,897
	Personal Income Fishing (Thousands of $)	667	700	787

Counties included in Area 3 (Table 10.) show a general increase in numbers of individuals within the selected occupations and industries, with the exception of Pender County which shows a decline from 1970-1990.

Table 10. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 3 for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database.

County	Occupation/Industry	1970	1980	1990
Brunswick County	Farm/Fish/Forest	370	668	1028
	Agri.,Fishing,Mining	505	645	971
Pender County	Farm/Fish/Forest	772	562	627
	Agri.,Fishing,Mining	892	669	690
New Hanover County	Farm/Fish/Forest	289	550	782
	Agri.,Fishing,Mining	564	615	984
Onslow County	Farm/Fish/Forest	754	869	996
	Agri.,Fishing,Mining	906	800	987

Snapper Grouper Fishing

For Area 3, the small community of Sneads Ferry, is unique in that the majority of the commercial reef fishermen fish with sea bass pots. According to the 1993 federal permit list for the South Atlantic region, there were 58 permit holders who indicated that sea bass pots were their primary gear type. Of those, 13 permit holders worked out of Sneads Ferry (Iverson, 1997).

Overall, 72% of fishermen using sea bass pots as their primary gear work out of home ports in North Carolina.

Area 4: Pamlico Area.

The Pamlico area includes these counties and communities (in parenthesis): Craven, Pamlico (Vandemere, Oriental), Beaufort (Bellhaven, Washington), Hyde (Ocracoke, Swanquarter, Englehard). Johnson and Orbach (1997) found that commercial fishermen in this area had three primary gear types, pots, gill nets, and trawls. In terms of annual fishing rounds Area 4 is the simplest to understand where two strategies are employed: gill netting and crab potting or trawling and crab potting. They go on to note that this simple strategy may signify few choices for fishermen in this area in the case of environmental or regulatory change (Johnson and Orbach 1997). Possible fishing communities within Area 4 might be: Vandemere and Oriental.

Table 11. Population and Economic Information for Counties included in Area 4.
Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 4 County		1993	1994	1995
Craven				
	Population	83,595	83,851	85,163
	Personal Income (Thousands of $)	1,450,296	1,508,353	1,626,657
	Per Capita Pers Income ($)	17,349	17,988	19,101
	Personal Income Fishing (Thousands of $)	386	405	----
Pamlico				
	Population	11,772	11,948	12,064
	Personal Income (Thousands of $)	179,384	186,131	199,576
	Per Capita Pers Income ($)	15,238	15,578	16,543
	Personal Income Fishing (Thousands of $)	2,714	2,851	3,211
Beaufort				
	Population	43,446	43,815	43,998
	Personal Income (Thousands of $)	674,788	711,961	756,048
	Per Capita Pers Income ($)	15,532	16,249	17,184
	Personal Income Fishing (Thousands of $)	1,339	1,406	1,580
Hyde				
	Population	5,374	5,339	5,362
	Personal Income (Thousands of $)	80,982	90,101	80,300
	Per Capita Pers Income ($)	15,069	16,876	14,976
	Personal Income Fishing (Thousands of $)	1,860	1,973	2,215

Pamlico county had the highest personal income from fishing for Area 4 from 1993 to 1995 with a steady increase over those three years (Table 11). Hyde county followed with Beaufort next; both showing an increase over time. For most counties in Area 4 (Table 12) the general trend seems to be an increase from 1970 to 1980 and then a decrease from 1980 to 1990 within these occupation and industry categories. Beaufort County shows an overall decrease from 1970-1990.

Table 12. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 4 for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Craven County	Farm/Fish/Forest	873	1136	832
	Agri.,Fishing,Mining	1129	1222	860
Pamlico County	Farm/Fish/Forest	245	498	442
	Agri.,Fishing,Mining	502	662	477
Beaufort County	Farm/Fish/Forest	1452	1393	1024
	Agri.,Fishing,Mining	2169	2123	1190
Hyde County	Farm/Fish/Forest	295	509	454
	Agri.,Fishing,Mining	442	579	511

Area 5: Carteret County

In Area 5 Johnson and Orbach (1997) found that commercial fishermen had three primary gear types, gill nets, trawls and hand harvest of shell fish. In terms of annual fishing rounds Area 5 did not show the clear gear stratification found in other areas. Shrimp trawling is the most central fishery, but pound netting, crab potting, and mechanized clamming also occur with shrimp trawling. (Johnson and Orbach 1997). Possible fishing communities within Area 5: Morehead City and Beaufort.

Table 13. Population and Economic Information for Counties included in Area 5. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 5		1993	1994	1995
County				
Carteret				
	Population	55,747	56,381	57,690
	Personal Income (Thousands of $)	935,032	985,484	1,076,753
	Per Capita Pers Income ($)	16,773	17,479	18,664
	Personal Income Fishing (Thousands of $)	2,783	2,871	3,207

Among North Carolina's coastal counties, Carteret county was second to Dare county (Table 13) in terms of personal income from fishing. In addition, Carteret County (Table 14) shows an marked increase from 1970 to 1980, then a decrease from 1980 to 1990, within the occupations of Farm/Fish/Forest and an overall increase in the number of Agriculture, Fishing and Mining industries.

Table 14. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Carteret County (Area 5) for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database.

County	Occupation/Industry	1970	1980	1990
Carteret County	Farm/Fish/Forest	225	1200	1158
	Agri.,Fishing,Mining	731	1234	1260

In a recent report on the importance of commercial fishing in Carteret county, Diaby (1997) found that Carteret county ranked first in poundage (96,652,314 lb) and second in dockside value ($20,618,486) in terms of commercial landings for North Carolina coastal counties. Finfish represented the 91% of total landings and 46% of total ex-vessel value. The most important species of finfish were: menhaden, flounder, croaker, weakfish and spot. Shellfish and crustaceans accounted for only 9% of all commercial landings but, represented over half of the value of landings during the period from 1974-1994. Employment by the commercial fishing industry, both full and part time for Carteret county was estimated to be 3,232 people for 1994 (Diaby, 1997). This number varies from those reported in the census data and emphasizes the problems in comparing these types of data. Since 1981 there have been about 105 to 140 licensed seafood dealers in Carteret county. The value of processed seafood peaked for the county in 1981 when scallops accounted for almost half of the value with a total value of $19,737,126. Since that time there has been a general decline in total value of processed seafood attributable to a decline in scallop landings. Menhaden was the most important single processed product over a fifteen year period from 1980 to 1994 (Diaby, 1997).

In estimating the economic impact of Carteret county commercial harvesting sector Diaby (1997) estimated $27 million in sales of goods and services and $11.66 million in value added. Total employment from commercial harvesting activities was estimated to be 3,371.

Sales of goods and services for the wholesaling and processing sector were estimated at $19 million, with $11 million n value added. There were an estimated 1,563 full and part time jobs created earning $6.55 million in wages (Diaby, 1997).

Overall, the activities of the commercial fishing industry created $46 million in sales of goods and services and $24 million in value added. There were 4,934 full and part time jobs which earned $14 million in wages (Diaby, 1997).

The recreational fishery spent approximately $70 million on fishing trips in Carteret county with $25.23 million in employ compensation and $47.61 in value added. There were 1,821 full and part time jobs associated with the recreational fishing industry in Carteret County.

The total impact of the coastal fishing industry on the economy of Carteret County was estimated to be $120.74 million with $71.32 million in value added. The total number of full and part time jobs was estimated at 6,755 with earnings of $38.94 (Diaby, 1997).

Snapper Grouper Fishing

The Morehead City/Beaufort area is located approximately 50 miles south of Ocracoke in Carteret County. This area is known for its sportfishing activity including several major tournaments each year. There is a small population of full time commercial reef fishermen in Morehead, however the majority of fishermen holding commercial permits are primarily part timers. Many of these fishermen divide their time between charter fishing during the peak tourist season (April through September) and commercial fishing in the winter months. Full time fishermen in this area reported fishing approximately 50 miles straight offshore and fishing from Hatteras to as far south as the South Carolina/Georgia line. Trip lengths vary with the size of the vessel, but the average trip length is 7 days and the larger boats carried up to 3 crew members (Iverson, 1997).

King Mackerel Fishery

The king mackerel fishery in North Carolina has grown steadily since 1980 and has leveled with catches repeatedly around one million pounds in recent years. From 1986 to 1990 the number of permits for Atlantic group king mackerel issued in North Carolina ranged from a low of 325 in 1987/88 to a high of 533 in 1989/90. Again, the majority of those permits were granted to hook and line fishermen. Present data indicates there were 448 commercial vessels permitted for king and Spanish mackerel in North Carolina (Vondruska, 1997).

4.3.3.1.3 South Carolina

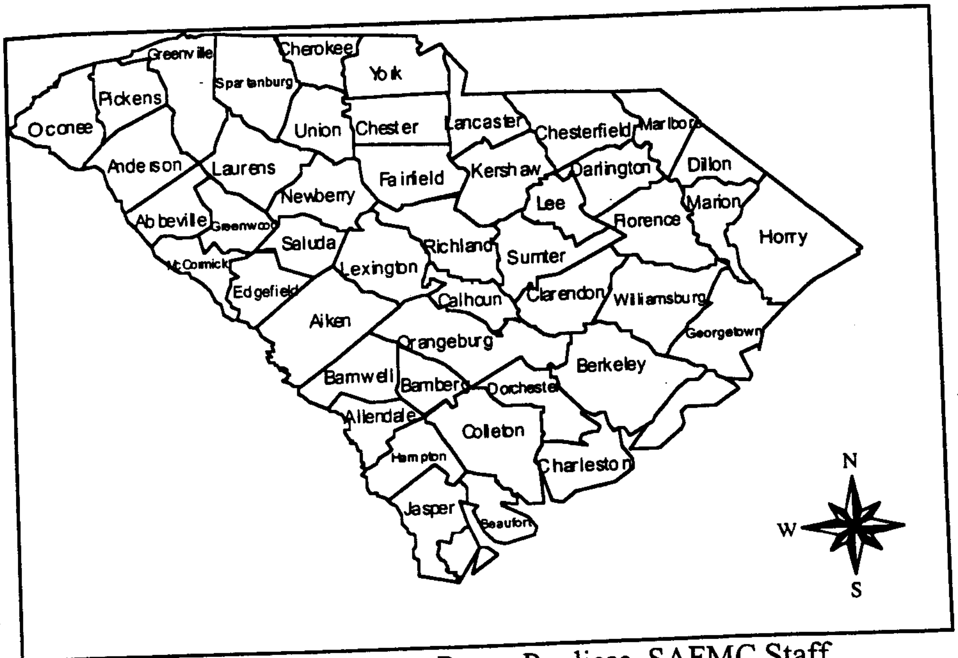


Figure 3. South Carolina Counties Source: Roger Pugliese, SAFMC Staff.

The 1990 Census of Population and Housing provides the following information for South Carolina regarding individuals who reported their occupation as fisher in Table 15. A total of 401 individuals claimed Fisher as their occupational title with less than half indicating it was a year round full time employment. There were few females who indicated such and they had a far lower mean annual income than males in this occupation.

Table 15. Number of Fishers and Mean Annual Income for South Carolina Fishers in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	**Other**	**Total**
Number of fishers			
Male	188	193	381
Female	6	14	20
Total	194	207	401
Mean Annual Income ($)			
Male	28,842	14,489	18,946
Female	750	5,000	2,403
Total	23,710	14,269	18,390

There were a total of 69 individuals who indicated their occupation as captain of a fishing vessel in the 1990 census of population and housing. and 7 of them were female according to Table 16 Again, females had a much lower mean annual income when compared to males.

Table 16. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for South Carolina in 1990. Source: U.S. Bureau of the Census

	Year Round/Full Time	Other	Total
Number of Captains			
Male	17	45	62
Female	7	0	7
Total	24	45	69
Mean Annual Income ($)			
Male	18,765	15,022	16,048
Female	9,000	0	9,000
Total	15,917	15,022	15,333

Horry County

The following descriptions for fishing communities in South Carolina are notes from Kim Iverson of South Carolina Department of Natural Resources. Kim has spent many months interviewing both commercial and recreational fishermen in South Carolina and other parts of the South Atlantic region as part of several research projects. Although the research was not intended to identify fishing communities, her notes represent the best available information on fishing communities for South Carolina.

Little River has a long history of fishing activity, both commercial and recreationally. The headboat operations date back to the 1940's. As of 1996, there were headboats operating in Little River. There are approximately 4 vessels that actively run charters and also commercial fish. Several full time snapper/grouper vessels operate out of the area. Little River also hosts an annual Blue Crab Festival each spring (Kim Iverson, SCDNR pers. comm., 1998).

Murrells Inlet has a large fleet of charter and headboats, with one marina hosting one of the Governor's Cup Billfishing Tournaments. There are several smaller fishing tournaments held in the area. There are fish houses in the community that deal primarily with finfish. There are no shrimp dealers. This area is also noted for it's large number of seafood restaurants that target the tourist market from Myrtle Beach (Kim Iverson, SCDNR pers. comm., 1998).

Major fishing tournaments held in Murrells Inlet are: March of Dimes Annual Flounder Tournament - Voyagers View Marina. Registration was by angler with approximately 200 anglers participating. Local tournament with many family participants. Primarily smaller boats < 25' participating. Tournament date May 17.; and the Marlin Quay Governor's Cup Billfish Tournament - Marlin Quay Marina. The last in the series of SC Gov. Cup. Total of 31 boats registered. July 23-26 (Kim Iverson, SCDNR pers. comm., 1998).

Major tournaments in North Myrtle Beach: Dock Holidays Governor's Cup Billfish Tournament - Dock Holiday's Marina. The first tournament in a series of 6 for the SC Governor's Cup. April 30 - May 3. Total of 25 boats entered; Frantic Atlantic King Mackerel Tournaments - North Myrtle Beach - Blue Marlin Yacht & Fishing Club. A two tournament series consisting of the Spring and Fall Classics. Total purse of $250,000 for the series. Total of 392 paid boat entries with an average of 4.09 anglers per boat. Tournament dates May 9-11, September 26-28; Evinrude Outboard King Mackerel Tournament - Oct. 11-12, Weigh-in stations at Dock Holidays Marina, Marlin Quay Marina and Georgetown Landing. 147 boats were registered; Yamaha Contender King Mackerel Classic - Weigh in stations at Dock Holidays

Marina, Marlin Quay Marina and Georgetown Landing. 125 boats registered; Fall Pier King Tournament - September 19-21 (Kim Iverson, SCDNR pers. comm., 1998).

One of the largest concentration of snapper grouper vessels is located in Murrells Inlet, SC. Most of the reef fishermen in this area are full time commercial fishermen and consider bandit reels to be the most effective way of catching snapper grouper. There is a wide variety of snapper grouper species off of Murrells Inlet, with gag grouper, scamp grouper and vermilion snapper being highly targeted. The average trip length is 5 days with some of the larger boats (>40 ft.) fishing up to 10 days. A few smaller bandit boats may stay out for 2-3- days. The Gulf Stream is approximately 62 miles offshore from Murrells Inlet. Most bandit boats fish between the 20-50 fathom line, concentrating on the 25 fathom curve. Winter weather dictates that fishermen fish shallow, in waters 60-90' deep. Several fishermen switch to sea bass trapping during the winter months (Iverson, 1997).

Horry County has shown a small increase in personal income from fishing that follows the general increase in personal income overall (Table 17).

Table 17. Population and Economic Information for Horry County, South Carolina.
Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

		1993	1994	1995
County				
Horry		148,385	152,435	157,834
	Population	2,543,793	2,744,260	3,013,059
	Personal Income (Thousands of $)	17,143	18,177	19,220
	Per Capita Pers Income ($)	81	129	169
	Personal Income Fishing (Thousands of $)			

Vessels in Murrells Inlet will fish an area from Frying Pan Shoals off southern NC, south to Savannah. The average boat has two crew members. It is interesting to note that fishermen stated a crew of 3 plus the captain was ideal for this area, but decreasing catches and increased costs have made it necessary to cut back on crew members (Iverson, 1997).

<u>Georgetown County</u>

The community of Georgetown has shrimp dealers who also deal in finfish and shellfish. Georgetown is host to the one of the SC Governor's Cup Billfish Tournaments along with several other smaller fishing tournaments. There are no headboats operating from the area and charter activity is limited. Georgetown is known for it's historic waterfront district (Kim Iverson, SCDNR pers. comm., 1998).

Major fishing tournaments in Georgetown County: Georgetown Landing Governor's Cup Billfishing Tournament - May 21-24, Georgetown Landing Marina. The oldest of the series tournaments with 45 boats participating.

Georgetown County shows an increasing personal income from fishing like Horry County in Table 18 but, personal income from fishing tends to be a larger percentage of overall personal income than in Horry County.

Table 18. Population and Economic Information for Georgetown County, South Carolina. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Georgetown				
	Population	49,371	49,966	50,835
	Personal Income (Thousands of $)	822,317	885,024	946,898
	Per Capita Pers Income ($)	16,656	17,713	18,627
	Personal Income Fishing (Thousands of $)	246	388	399

Charleston County

McClellanville is a small community with a long history of commercial shrimping. McClellanville has a large shrimp fleet. At any given time (dependent upon the season) there can be as many as 20 shrimp boats at the docks. Shrimp wholesale dealers are also present within the community. McClellanville hosts an annual Blessing of the Fleet Festival each spring. Shem Creek (Mt. Pleasant) hosts a mixture of commercial and recreational fishing activity along with a number of seafood restaurants, a retail seafood market and a waterfront hotel. There are also headboats operating out of Shem Creek along with charter operations. There is a large permanent shrimp fleet and many shrimp boats visit seasonally. At any give time there are an average of 30 shrimp boats along the creek. Shrimp dealers along the creek also buy and sell finfish from the trawlers. There are several offshore fishing boats including longline and snapper/grouper boats. Several shellfishermen and crabbers do business along the creek. Each spring, Mt. Pleasant hosts an Annual Blessing of the Fleet for the shrimp boats.

In Folly Beach there is a concentration of commercial fishing vessels and several fish houses who handle offshore finfish, shellfish, shrimp and crabs. Rockville is a historical small community located at the south end of Wadmalaw Island. There are commercial dealers who handle shrimp, inshore fish, offshore finfish and some shellfish. On Edisto Island there are several commercial seafood dealers. There are approximately 10 shrimp boats that operate there, fluctuating with the season. The dealers handle primarily shrimp and in-shore species along with shellfish and blue crabs. There is also a large "harvest" of horseshoe crabs. These crabs are "bled" for their blood that is used in cancer research and returned to the water. Edisto Island is also host to the annual SC Governor's Cup Billfish Tournament. Charter activity here is limited. Bennett's Point is a small community south of Edisto with shrimping operations in the community. There are 10-15 small boat shrimpers that live in Walterboro and fish out of Bennett's Point (Kim Iverson, SCDNR pers. comm., 1998).

Table 19. Population and Economic Information for Charleston County, South Carolina. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Charleston	Population	297,888	287,139	281,068
	Personal Income (Thousands of $)	5,653,489	5,879,506	6,083,636
	Per Capita Pers Income ($)	18,979	20,476	21,645
	Personal Income Fishing (Thousands of $)	3,188	3,809	----

Charleston County (Table 19) has a higher personal income from fishing than the previous two counties, but has a much larger overall dollar value for personal income overall.

Major fishing tournaments in the Charleston County area: SCSSA (South Carolina Saltwater Sportfishing Assoc.) Early Bird - Ashley Marina. Approximately 25 registered boats. April 19. Multi-species tournament; James Island King Mackerel Tournament - James Island

Yacht Club, May 24; Wild Dunes Governor's Cup Billfish - June 11-14. Total of 46 registered boats; Bohicket Invitational Governor's Cup Billfish - June 25-28. Total of 48 registered boats. Bohicket Marina on John's Island; Lowcountry Angler's Inshore Tournament - June 28. Multi-species tournament held at the East Cooper Outboard Motor Club on Gold Bug Island in Mt. Pleasant. Registration by angler, with approximately 200 anglers registered; SCSSA Sailfish XV - Ashley Marina in Charleston. Club sponsored tournament with approximately 25 boats registered. Sailfish, tuna, dolphin & wahoo. August 8-10; Fishing For Miracles King Mackerel Tournament - Ripley's Light Marina. Large King tournament with over 200 boats entered. August 14-16; Alison Oswald, Sr. Memorial Tournament - James Island Yacht Club. Local tournament with approximately 75 boats participating. Multi-species. Aug. 23; Edisto Marina Governor's Cup Billfish Tournament - July 16-19. One of the oldest and largest of the Billfish Series. 46 Boats registered. Edisto Island (Kim Iverson, SCDNR pers. comm., 1998).

Beaufort County

In Frogmore there are 8 commercial dealers which are home to over 50 shrimpers. This does not include the many individuals with shrimp boats in their back yards. The dealers primarily handle shrimp but others may also handle crabs and shellfish. There is a large blue crab industry on nearby Lady's Island. There are several commercial seafood dealers in the Port Royal area with over 30 shrimp boats. There are also commercial crabbers, shad fishermen and offshore finfishermen here. There are a small number of charter vessels operating out of this area also. Hilton Head Island primarily caters to the tourist trade. There are several headboats operating on Hilton Head. These boats make half-day trips and night trips for shark fishing. There are four major marinas that offer charter fishing. Commercially, Hilton Head had 4 seafood dealers and approximately 12-15 shrimp boats (Kim Iverson, SCDNR pers. comm., 1998).

Data on personal income from fishing in Table 20 for Beaufort County may have been excluded due to confidentiality issues.

Table 20. Population and Economic Information for Beaufort County, South Carolina.
Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

		1993	1994	1995
County				
Beaufort				
	Population	94,375	97,293	100,017
	Personal Income (Thousands of $)	2,057,250	2,194,774	2,373,921
	Per Capita Pers Income ($)	21,799	22,558	23,774
	Personal Income Fishing (Thousands of $)	----	----	----

Major fishing tournaments in Beaufort County: 42nd Annual Beaufort County Water Festival Fishing Tournament - June 28. Held in conjunction with the annual Beaufort Water Festival; Hilton Head Kingfish Classic - Schillings Marina, Hilton Head Island. July 10-12. Registration by angler with a total of 49 registered; Dottie Dunbar Women's Tournament - Palmetto Bay Marina, Hilton Head. Women's only multi-species inshore tournament. Total of 49 anglers registered. October 4 (Kim Iverson, SCDNR pers. comm., 1998).

Possible fishing communities in South Carolina: Charleston, Mt. Pleasant, Hilton Head, Port Royal, Frogmore (St. Helena), Bennett's Point, Edisto Beach, Rockville, Folly Beach, Shem Creek, McClellanville, Georgetown Waterfront, Murrell's Inlet, Little River (most of these locations are designated ports of landing)

Counties in South Carolina have seen a general increase in these occupations and industries over the past three decades (Table 21), with the exception of Horry County which has seen a slight decreasing trend.

Table 21. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for South Carolina Coastal Counties for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	**Occupation/Industry**	**1970**	**1980**	**1990**
Horry County	Farm/Fish/Forest	2627	2542	2310
	Agri.,Fishing,Mining	2843	2653	2110
Georgetown County	Farm/Fish/Forest	403	558	597
	Agri.,Fishing,Mining	552	856	690
Charleston County	Farm/Fish/Forest	810	1697	2056
	Agri.,Fishing,Mining	1256	1938	2316
Beaufort County	Farm/Fish/Forest	436	938	966
	Agri.,Fishing,Mining	698	1087	1111
Colleton County	Farm/Fish/Forest	532	614	730
	Agri.,Fishing,Mining	787	705	782

For the Charleston, South Carolina MSA (Table 22) there are 113 individuals who indicated fishing as their year round occupation . Another 102 individuals indicated that it is a part time or seasonal occupation for them. This represents over half of those individuals in South Carolina who indicated the occupation as fishing from Table 15. The Charleston, SC MSA includes Berkely, Charleston and Dorchester counties.

Table 22. Number of Individuals in Occupation of Fishing By Work Status and Gender for the Charleston, SC MSA in 1989. Source: 1990 Census Of Population And Housing.

	Year Round Full Time	Other	Total
Male	102	102	204
Female	11	0	11
Total	113	102	215

4.3.3.1.4 Georgia

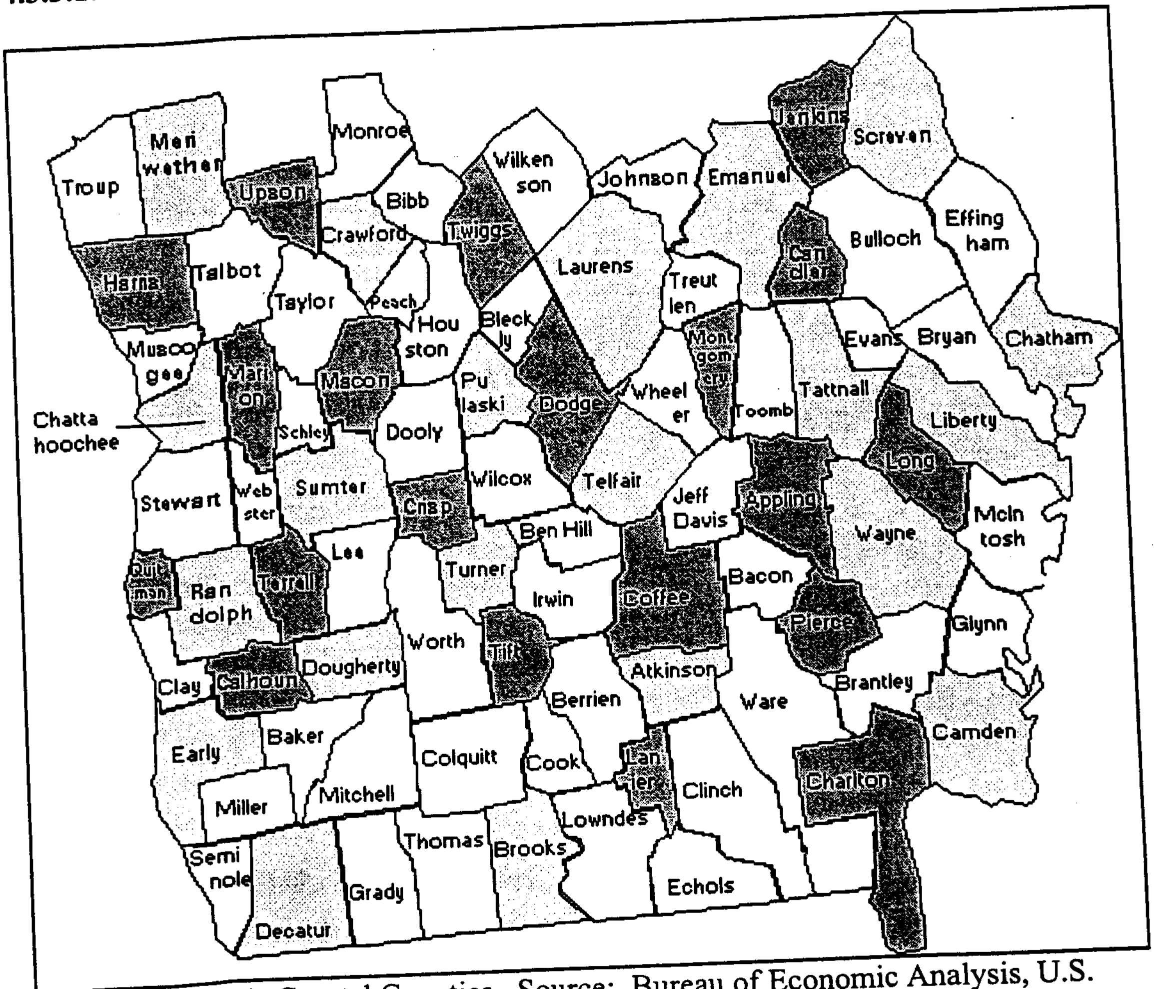


Figure 4. Georgia Coastal Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

The 1990 Census of Population and Housing provides the following information for Georgia regarding individuals who reported their occupation as fisher in Table 23. A total of 536 individuals claimed Fisher as their occupational title with less than half indicating it was a year round full time employment. There were few females who indicated such and they had a far lower mean annual income than males who indicated it was a full time occupation. However, females who indicated it was other than full time had a much higher mean income than any other category. This may be due to a low sample size, however.

Table 23. Number of Fishers and Mean Annual Income for Georgia in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	222	295	518
Female	11	7	18
Total	234	302	536
Mean Annual Income ($)			
Male	19,139	11,082	15,058
Female	8,600	25,000	20,080
Total	18,813	12,024	15,308

Shrimping

In their 1975 report, Nix et. al., found a total of 32 commercial docks in six Georgia coastal counties. Those docks and shrimp trawlers were distributed as follows: Camden Co. - 5 docks and 33 trawlers; Glynn Co. - 5 docks and 74 trawlers; McIntosh Co. - 12 docks and 111 trawlers; Liberty Co. - 1 dock and 18 trawlers; Bryan Co. - 1 dock and 2 trawlers; and finally Chatham Co. - 8 docks and 69 trawlers. This information is outdated and certainly does not represent the current status and location of shrimp trawlers in Georgia. However, the report does represent the kinds of information that can be extremely helpful in identifying fishing communities.

Snapper Grouper Fishing

The coast of Georgia contains a small concentration of full-time reef fishermen that fish primarily with bandit reels. Their fishing patterns are similar to those found in SC with vessels fishing from northern Florida north to the SC/NC line (Iverson, 1997).

Possible fishing communities in Georgia: Savannah, Brunswick, St. Marys, Jekyll Island, and Darien.

Table 24. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for Georgia in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	17	21	38
Female	0	0	0
Total	17	21	38
Mean Annual Income ($)			
Male	25,706	1,976	12,592
Female	0	0	0
Total	25,706	1,976	12,592

Table 25. Population and Economic Information for Chatham County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Chatham	Population (number of persons)	224,050	225,779	226,554
	Personal income (thousands of dollar	4,569,113	4,810,530	5,087,638
	Per capita personal income (dollars)	20,393	21,306	22,457
	Personal Income Fishing (Thousands of $)	650	(D)	25

Table 26. Population and Economic Information for Bryan County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Bryan	Population	18,827	20,008	21,212
	Personal Income (Thousands of $)	274,738	307,258	342,128
	Per Capita Pers Income ($)	14,593	15,357	16,129
	Personal Income Fishing (Thousands of $)	251	359	----

Table 27. Population and Economic Information for Liberty County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Liberty	Population	56,625	58,827	58,571
	Personal Income (Thousands of $)	636,042	669,454	709,468
	Per Capita Pers Income ($)	11,233	11,380	12,113
	Personal Income Fishing (Thousands of $)	----	90	97

Table 28. Population and Economic Information for McIntosh County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
McIntosh	Population	8,985	9,153	9,372
	Personal Income (Thousands of $)	110,187	116,171	125,645
	Per Capita Pers Income ($)	12,263	12,692	13,406
	Personal Income Fishing (Thousands of $)	3,619	4,486	----

Table 29. Population and Economic Information for Glynn County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Glynn	Population	64,759	64,956	65,450
	Personal Income (Thousands of $)	1,322,745	1,400,544	1,505,337
	Per Capita Pers Income ($)	20,426	21,558	23,000
	Personal Income Fishing (Thousands of $)	328	343	351

Table 30. Population and Economic Information for Camden County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Camden				
	Population	39,712	41,262	40,819
	Personal Income (Thousands of $)	502,639	542,385	556,622
	Per Capita Pers Income ($)	12,657	13,145	13,636
	Personal Income Fishing (Thousands of $)	1,889	2,431	2,484

Georgia coastal counties have seen a general increase in these occupations and industries with the exception of Liberty County which has shown a decrease from 1970-1990.

Table 31. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Georgia Coastal Counties for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Bryan County	Agri.,Fishing,Mining	161	100	200
	Farm/Fish/Forest	121	135	136
Chatham County	Agri.,Fishing,Mining	558	686	1103
	Farm/Fish/Forest	228	704	1062
Liberty County	Agri.,Fishing,Mining	332	146	152
	Farm/Fish/Forest	242	205	157
McIntosh County	Agri.,Fishing,Mining	233	266	169
	Farm/Fish/Forest	27	260	193
Glynn County	Agri.,Fishing,Mining	261	482	593
	Farm/Fish/Forest	84	581	712
Camden County	Agri.,Fishing,Mining	209	126	176
	Farm/Fish/Forest	106	110	205

4.3.3.1.5 Florida

Florida's eastern coastline is made up largely of metropolitan counties. This is primarily due to the increases in population for Florida's coastal counties over the past 50 years. Florida's coastline has become a very popular retirement destination and tourist attraction. Because they are largely metropolitan, fishing communities here may be subsumed into these larger metropolitan areas and difficult to identify. Data presented from the most recent Census will also show that in relation to the larger economy, fishing will contribute very little at the county level for most coastal counties. Over the years, with the demographic changes following the inmigration of retirees and tourists and the subsequent economic transition, few fishing communities will have survived as distinct communities.

The data presented in Table 32 shows Florida as having almost 6,000 individuals claiming fisher as their occupation in the 1990 census; 381 of those individuals were female. Mean annual income is highest for those reporting fishing as a full time occupation with women reporting a lower mean annual income in all categories.

Table 32. Number of Fishers and Mean Annual Income for Florida in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	2,698	2,844	5,544
Female	111	270	381
Total	2,809	3,116	5,925
Mean Annual Income ($)			
Male	23,288	11,794	17,388
Female	17,285	11,511	13,193
Total	23,051	11,770	17,118

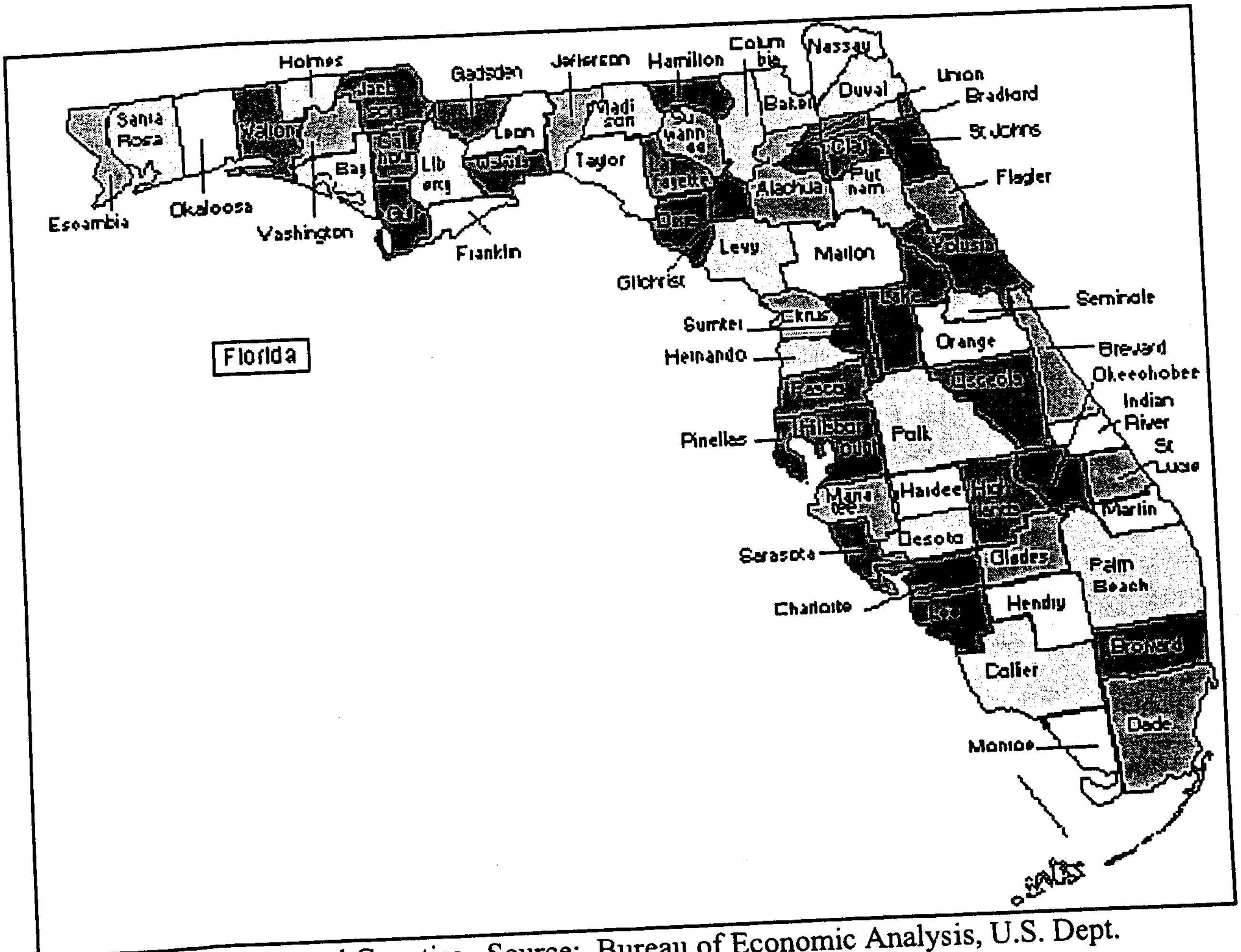


Figure 5. Florida Coastal Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

There were over 1100 individuals from Florida who reported their occupation as captain of a fishing vessel during the 1990 census, with 51 of them being female (Table 33). Again, mean annual income was highest for full time workers and females reported lower mean annual income for both full time and other work.

Table 33. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for Florida in 1990 Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	430	633	1,063
Female	26	25	51
Total	456	658	1,114
Mean Annual Income ($)			
Male	25,993	21,274	23,183
Female	8,487	15,420	11,885
Total	24,995	21,052	22,666

Nassau County (Table 34) showed an increase in personal income from fishing over the time period from 1993 to 1995 which reflects the general increase in population and personal income overall for the county.

Table 34. Population and Economic Information for Nassau County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Nassau				
	Population	48,355	49,565	50,717
	Personal Income (Thousands of $)	954,342	1,003,920	1,089,793
	Per Capita Pers Income ($)	19,736	20,255	21,488
	Personal Income Fishing (Thousands of $)	1,540	1,918	2,068

Duval County (Table 35) shows slow growth in population over the three years listed, but does show growth in personal income from fishing from 1993 to 1994. There was a slight decrease in personal income from fishing reported from 1994 to 1995.

Table 35. Population and Economic Information for Duval County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Duval				
	Population	701,267	703,152	705,014
	Personal Income (Thousands of $)	14,111,822	14,724,897	15,748,121
	Per Capita Pers Income ($)	20,123	20,941	22,337
	Personal Income Fishing (Thousands of $)	2,272	3,658	3,335

St John's County (Table 36) had some growth in personal income from fishing from 1993 to 1994 but no data were available for 1995 to indicate whether that trend continued.

Table 36. Population and Economic Information for St. John's County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
St. Johns				
	Population	94,480	98,377	101,966
	Personal Income (Thousands of $)	2,394,764	2,612,557	2,869,300
	Per Capita Pers Income ($)	25,347	26,557	28,140
	Personal Income Fishing (Thousands of $)	432	502	- - - -

According to Table 37, Flagler County had no individuals reporting personal income from fishing for the time period 1993 to 1995. Volusia County also has no personal income from fishing listed in Table 38, but data were not included due to confidentiality issues.

Table 37. Population and Economic Information for Flagler County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Flagler				
	Population	35,868	37,894	40,260
	Personal Income (Thousands of $)	571,528	631,959	692,269
	Per Capita Pers Income ($)	15,934	16,677	17,195
	Personal Income Fishing (Thousands of $)	0	0	0

Table 38. Population and Economic Information for Volusia County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Volusia				
	Population	397,372	405,515	410,115
	Personal Income (Thousands of $)	6,845,402	7,235,060	7,772,063
	Per Capita Pers Income ($)	17,227	17,842	18,951
	Personal Income Fishing (Thousands of $)	----	----	----

Indian River County saw an increase in personal income from fishing from 1993 to 1994 according to Table 39, but saw a decrease from 1994 to 1995. St. Lucie County (Table 40) may have had a similar trend although data from 1993 are missing and the trend is not clear.

Table 39. Population and Economic Information for Indian River County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Indian River				
	Population	94,184	95,374	96,263
	Personal Income (Thousands of $)	2,686,514	2,827,427	3,065,533
	Per Capita Pers Income ($)	28,524	29,646	31,845
	Personal Income Fishing (Thousands of $)	1,340	1,826	1,707

Table 40. Population and Economic Information for St. Lucie County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
St. Lucie				
	Population	165,120	169,284	171,914
	Personal Income (Thousands of $)	2,719,602	2,840,752	3,051,018
	Per Capita Pers Income ($)	16,470	16,781	17,747
	Personal Income Fishing (Thousands of $)	----	1,855	1,303

Table 41. Population and Economic Information for Broward County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce

County		1993	1994	1995
Broward				
	Population	1,353,279	1,358,585	1,412,942
	Personal Income (Thousands of $)	32,716,045	34,273,950	37,007,667
	Per Capita Pers Income ($)	24,175	24,736	26,192
	Personal Income Fishing (Thousands of $)	658	816	----

The trend in personal income from fishing for Broward County is not clear as data from 1995 are missing from Table 41 because of confidentiality. Brevard County (Table 42) shows a decrease in personal income from fishing during 1994 to 1995, but overall shows a much larger percentage of personal income coming from fishing than most counties previous.

Table 42. Population and Economic Information for Brevard County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Brevard				
	Population	435,546	443,337	450,238
	Personal Income (Thousands of $)	8,564,204	8,938,218	9,341,030
	Per Capita Pers Income ($)	19,663	20,161	20,747
	Personal Income Fishing (Thousands of $)	3,600	4,690	3,797

Martin County has one of the highest per capita incomes reported over the three year period according to Table 43. There was also a significant increase in personal income from fishing from 1993 to 1994 which decreased in 1995. Palm Beach County, with an even higher per capita income, showed an increase in personal income from fishing from 1993 to 1994 with no data available for 1995 (Table 44).

Table 43. Population and Economic Information for Martin County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Martin				
	Population	107,238	109,194	110,495
	Personal Income (Thousands of $)	3,406,064	3,521,665	3,815,294
	Per Capita Pers Income ($)	31,762	32,251	34,529
	Personal Income Fishing (Thousands of $)	270	1,658	819

Table 44. Population and Economic Information for Palm Beach County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Palm Beach				
	Population	933,644	957,522	976,358
	Personal Income (Thousands of $)	30,994,531	32,423,719	35,204,121
	Per Capita Pers Income ($)	33,197	33,862	36,057
	Personal Income Fishing (Thousands of $)	1,464	1,902	----

Dade County shows a steady growth in personal income from fishing for the time period listed in Table 45. Monroe County shows, by far, the highest personal income from fishing for any Florida county and most likely any county in the South Atlantic according to Table 46.

Table 45. Population and Economic Information for Dade County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Dade				
	Population	1,985,373	2,011,571	2,046,078
	Personal Income (Thousands of $)	39,110,301	40,344,476	43,087,320
	Per Capita Pers Income ($)	19,699	20,056	21,058
	Personal Income Fishing (Thousands of $)	1,247	1,479	1,897

Table 46. Population and Economic Information for Monroe County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Monroe				
	Population	81,737	81,461	81,152
	Personal Income (Thousands of $)	1,982,209	2,054,326	2,208,152
	Per Capita Pers Income ($)	24,251	25,219	27,210
	Personal Income Fishing (Thousands of $)	13,506	15,558	16,723

Recently, data were compiled from the last three census and placed into a user friendly interface through a MARFIN grant by the Louisiana Population Data Center, Louisiana State University (C. M. Tolbert, et al. 1998). Those data provide a time series of information from the last three census with the ability to compare several variables at the state,. county and place level. Census places are incorporated and Census designated places of 2500 or more persons. The tables presented below incorporate the data included in the MARFIN SocioDemographic Database for the coastal counties outlined above with a focus on the occupational classification of Farm/Fish/Forest and the industry classification of Agriculture, Fishing, and Mining. These classifications are inclusive of those within the occupation and industry of fishing, but not exclusive of others, therefore it is difficult to know the exact number of individuals who have indicated their occupation or business is fishing. We can only assume that whatever trend appears over the time corresponds to the occupation of fishing as well as the others.

Data covering Metropolitan Statistical Areas are provided because it includes a more detailed occupational breakdown, but unfortunately geographic boundaries expand as most MSAs encompass more than one county. In some cases, MSAs were not used because the area covered did not correspond with the coastal areas within the South Atlantic region. As mentioned earlier, these data are what is currently available. Further analysis is constrained by variety of issues relating to data computability and availability at each place level of analysis. As mentioned before more research on fishing communities will be required before a more complete definition and identification can be accomplished.

Examining census data at the level of Metropolitan Statistical area reveals greater detail for occupation, but the scale changes as MSAs often times encompass more than one county. Metropolitan area (MA) is a large population nucleus, together with adjacent communities that have a high degree of economic and social integration with that nucleus. Metropolitan Areas must contain either a place with a minimum population of 50,000 or a Census Bureau-defined urbanized area and a total MA population of at least 100,000. An MA comprises one or more central counties and also may include one or more outlying counties that have close economic and social relationships with the central county. Metropolitan statistical areas (MSA's) are relatively freestanding MA's and are not closely associated with other MA's. These areas typically are surrounded by nonmetropolitan counties. See Appendix ?? for details on the parameters for the coastal MSAs included in this discussion.

When you look at the occupations of farming, fishing and forestry for Florida coastal counties in Table 47, over the past 20 years there is, in general, a steady increase in the number of individuals within these occupations and industries.

Table 47. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for East Florida Coastal Counties from 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Nassau County	Farm/Fish/Forest	371	427	559
	Agri.,Fishing,Mining	501	462	606
Duval County	Farm/Fish/Forest	1237	2782	3729
	Agri.,Fishing,Mining	2536	2959	4324
St.Johns County	Farm/Fish/Forest	794	813	1002
	Agri.,Fishing,Mining	1012	883	976
Flagler County	Farm/Fish/Forest	145	314	408
	Agri.,Fishing,Mining	186	298	403
Volusia County	Farm/Fish/Forest	1308	3150	4917
	Agri.,Fishing,Mining	2511	3407	5606
Indian River County	Farm/Fish/Forest	991	1907	2042
	Agri.,Fishing,Mining	1454	2361	2217
St. Lucie County	Farm/Fish/Forest	2602	2710	3147
	Agri.,Fishing,Mining	3253	3252	3342
Broward County	Farm/Fish/Forest	1982	7358	9425
	Agri.,Fishing,Mining	5354	7756	10317
Brevard County	Farm/Fish/Forest	764	1772	3369
	Agri.,Fishing,Mining	1394	2279	3585
Martin County	Farm/Fish/Forest	964	1838	1983
	Agri.,Fishing,Mining	1268	2032	2086
Palm Beach County	Farm/Fish/Forest	6552	9676	13261
	Agri.,Fishing,Mining	9791	11780	15155
Dade County	Farm/Fish/Forest	4804	11257	14894
	Agri.,Fishing,Mining	9682	13708	16926
Monroe County	Farm/Fish/Forest	163	1769	1729
	Agri.,Fishing,Mining	920	1932	1860

The following table includes only those individuals who reported their occupation as fishing for the following Metropolitan Statistical Areas (MSA) within Florida.

Table 48. Number of Individuals in Occupation of Fishing By Work Status and Gender for Florida MSA in 1989. Source: 1990 Census Of Population And Housing.

		Year Round Full Time	Other	Total
Jacksonville	Male	151	210	361
	Female	15	49	64
	Total	166	259	425
West Palm Beach		Year Round Full Time	Other	Total
	Male	94	47	141
	Female	0	0	0
	Total	94	47	141
Miami		Year Round Full Time	Other	Total
	Male	254	254	508
	Female	0	30	0
	Total	254	284	538

Snapper Grouper Fishery Profile

Concentrations of reef fishermen can be found in the communities of Mayport, Port Orange and New Smyrna, north of Cape Canaveral. Bandit reels are the primary gear used for reef fishing in these areas, although a few bottom longline vessels are present. In northern Florida, bandit fishermen report trips lasting 5-6 days and fish 30-50 miles offshore. They average between 2 to 3 crew members depending on vessel size and gear. Vessels from the Mayport area reported fishing from the Georgia line south to the Daytona area. The larger longline vessels are required by regulations to fish past the 50 fathom line and reported trip lengths of up to 10 days, fishing as far as 100 miles from shore. These bottom long line vessels fish for deep water species such as tilefish in water 600 - 900' deep (Iverson, 1997).

King Mackerel Fishery Profile

McKenna (1994) identified the number of fishermen in Florida reporting landings of king mackerel (based on Saltwater Products Licenses) from 1987 to 1993 as varying from 1,500 to 2,222. From 1986 to 1990 the number of commercial permits for Atlantic migratory group king mackerel ranged from a high of 888 in 1989/90 fishing season to low of 785 in the 1987/88 fishing year. The percentage of those permits which were hook and line fishermen for those years ranged from 89% in 86/87 to 78% in 1990. There were 1654 vessels permitted for commercial king mackerel and Spanish mackerel in Florida for the 1993-94 fishing year. The number of permitted vessels was divided with 846 and 808 allocated to the East and West coasts respectively. How many of those vessels landed king mackerel is unknown at this time. Catch per unit of effort data seems fairly consistent for the southeastern region of the Atlantic group king mackerel with an average CPUE of between 200-300 lbs/trip (McKenna, 1994). Most of the commercial landings of Atlantic group king mackerel are made by hook and line fishermen. In addition, because most landings of Atlantic group king mackerel are in Florida and the most information that exists is on the Florida fishery, the following description will focus primarily on the Florida fishery unless noted otherwise.

King Mackerel Hook and Line Fleet

There were approximately 203 full and part time vessels in the hook and line mackerel fleet in 1980. Vessel size ranged from 22-44 feet in length. Today, the Florida South Atlantic troll fishery is composed of about 100 full-time and 100 part-time operations, about 150 of them are dependent upon king mackerel. Full-time fishermen operate primarily out of Jupiter, Port Salerno, Fort Pierce, Sebastian, and Rivera Beach. Normally, there is one fisherman to a boat. Part-time fishermen operate mostly out of Palm Beach, frequently two or three fishermen per boat. Approximately 40 percent of the full time trollers switch to bottom fishing for various reef fish after the Gulf king mackerel season. The remainder of these full time trollers tie up their boats when the Gulf king mackerel season ends. Some engage in various non-fishing jobs, while the majority reportedly wait for the opening of the Atlantic king mackerel season (GMFMC & SAFMC, 1994).

During the peak season about 75 to 100 troll vessels and 16 to 20 net vessels target king mackerel in the Keys. Net vessels usually start fishing late December, although some of these vessels troll for mackerel before net fishing becomes more practicable. Most king mackerel fishermen in the Keys target other species such as stone crab, spiny lobster, and reef fish throughout the year.

King Mackerel Net Fishing Fleet

There were approximately 89 large gill net vessels in Florida including full and part time in 1980. The vessels ranged in size from 30-65 feet. These vessels fished Spanish and king mackerel during the winter, but also targeted lobster, swordfish and bait fish during other times of the year. Vessels over 40 feet usually employed a power roller to haul nets. The large gill net fleet was primarily located from Florida's central east coast in Ft. Pierce, throughout the Florida Keys to the central west coast as far north as Cortez. There were also a few large boats in the Panhandle area of Port St. Joseph (Centaur Associates, 1981).

Approximately 87% of captains in the large gill net fleet at that time depended entirely upon fishing for their income. Net fishermen, then as they do today, have the options of participating in the Spanish mackerel fishery, trolling for king mackerel, and fishing with nets or hook and line for Atlantic group king mackerel after March (Centaur Associates 1981).

Today, there are twelve large net boats located in the Keys that may fish Atlantic group king mackerel occasionally. These vessels have a capacity of up to 40,000 pounds per trip and have had large catches of king mackerel in the past. There does not seem to be a small gill net boat sector for Atlantic king mackerel. In Monroe County there are 16 to 20 large net boats currently participating in the king mackerel fishery, some with capacity to land up to 50,000 pounds. There are another 6 to 12 small net boats in south-west Florida ready to enter the fishery when the opportunity arises. These vessels are 30 to 40 feet in length with capacities of 5,000 to 10,000 pounds.

There has been a general decline in net catches along the Florida east coast. This may be attributed to regulations like the prohibition of drift nets and purse seines, but also stems from the recent net ban in Florida state waters.

King Mackerel Dealers

McKenna (1994) identified over 200 dealers in Florida who had handled king mackerel since 1987. In 1992 there were 240 who reported landings of king mackerel. Most of those dealers purchased king mackerel ten or fewer times per season and handled less than 5000 pounds. There were over twenty dealers who handled 100,000 pounds or more during the 1992 season (McKenna, 1994) .

Possible fishing communities in Florida: Mayport, Port Orange, New Smyrna, Sebastian, Port Salerno, Rivera Beach, Ft. Pierce, Jupiter, West Palm Beach, Boyton Beaches, The Keys -- Upper Keys: Key Largo, Tavernier; Middle Keys - Islamorada, Marathon; Lower Keys; and Key West.

4.3.3.1.6 Other Community related Analysis

In a recent survey of snapper grouper fishermen in the South Atlantic questions were posed concerning a fishermen's tenure within a community and attitudes towards community change. The results in Table 49 show that the majority of fishermen feel their community has stayed the same or has changed for the better. A larger percentage of inactive than active snapper grouper fishermen feel that their community has changed for the worse. Well over half of fishermen interviewed had been in their present community for twenty years or more. Over sixty percent of inactive fishermen have lived in their community for twenty years or more, while over fifty percent of active fishermen have lived in their communities for 19 years or less. The mean number of years a fishermen had resided in their present community was twenty years or more for North Carolina, South Carolina and Florida. In comparison Georgia snapper grouper fishermen had an average tenure in their communities of 6.5 years. This may be an artifact of the small sample size in Georgia as only seven fishermen from that state were interviewed, but could also be reflective of the nature of snapper grouper fishing in Georgia (Rhodes et al., 1997).

Table 49. Snapper Grouper Fishermen's Tenure and Attitude toward Change in their Present Community. Source: Socio-demographic Assessment of Commercial Reef Fishermen in the South Atlantic Region. 1997.

	Active (%)	Inactive (%)
Feel Your Community has changed?	(N=201)	(N=26)
For the better	41.8	30.8
For the worse	32.1	46.2
Stayed the same	25.9	23.1
	Active (Yrs)	Inactive (Yrs)
Number of Years in Present Community?	(N=201)	(N=26)
2-12	27.6	25.9
13-19	32.0	11.1
20-35	19.5	33.4
36 <	20.9	29.6

These perspectives on an individual's feelings toward a community become important when that person must face significant changes regarding his/her occupation, as is often the case when limited entry or some other form of fisheries management is implemented. An individual's commitment toward their community and sense of belonging will influence decisions on whether to stay in fishing or within a particular community. The impacts become important for the community if many individuals face the same decision. When active fishermen were asked what is the likelihood of moving to a new town in the next 2-3 years most responded that it is was unlikely, however, over 27% indicated they were not sure or it was likely. When both inactive and active fishermen were asked the likelihood of leaving commercial fishing altogether 46% of inactive fishermen said it was likely or very likely, while only 11% of active fishermen indicated such a likelihood. (Rhodes et al., 1997). These type of data at the community level would contribute much to the understanding of possible impacts of future fisheries management.

4.3.3.1.7 Data Needs

As mentioned earlier, the data presented here is what is currently available and readily accessible. It is very limiting and does not provide a sufficient amount of detail needed to define and identify fishing communities. Therefore, the likelihood of realistic impact assessment of future fishing regulations on fishing communities is not good.

At the present the NMFS does not collect data on fishing communities. Therefore, it is impossible to realistically identify fishing communities in this amendment. There is a tremendous need for research to be conducted on a continuous basis to collect this information. Both state and federal government agencies have access to current information which can inform the process of identifying fishing communities. Permit databases for fishing licenses, wholesale and retail licenses, boat registrations, marina permits, boat landing locations, and many others exist now. Putting that information into one database is a monumental task, but should be undertaken soon. Geographic Information System software is now available and being used to compile much of the data regarding habitat. The same type of databases need to be created regarding fishing communities. Spatial analysis of the variables that help identify and define fishing communities can give useful insight into the changes that affect these coastal communities.

It is unlikely that Council Staff would be able to gather these data. Council staff have in the past, with the cooperation of industry, been able to gather important information about a particular fishery, but were criticized for not following OMB guidelines. The difficulty with following OMB guidelines is that approval of data gathering tools is too time consuming. Councils are often on a timeline to develop FMPs which does not allow for a lengthy approval process. The South Atlantic Council staff has sufficient expertise with this type of data collection that design, implementation and analysis can often take place during an extremely short time period with little burden upon the public. In fact, industry is often eager to provide these type of data for consideration during development of an FMP, but don't have the expertise to offer data a form that can be used by Council staff.

Data collection is critical to the future of impact assessment of fishing communities. Standards must be set and data need to be collected. At present, the ACCSP is attempting to set those standards and has included social and economic data in that program. The ACCSP Technical Source Document IV contains detailed social and economic data needs and draft survey instruments. Social and economic data collection projects should at least collect the minimum data elements. Support of ACCSP can be an important step in meeting the future needs of the councils with regard to fishing communities. In addition, another guideline for the types of data needed can be found in the Southeast Social and Cultural Data Analysis Plan (NMFS, 1994). The plan was designed to address many of the current social and cultural information needs for the three councils in the Southeast."

4.0 ECOSYSTEM CONSIDERATIONS

4.1 Introduction

As a result of the Sustainable Fisheries Act Amendment to the Magnuson-Stevens Fishery Conservation and Management Act in 1996 the Councils and the NMFS have been mandated to use an ecosystem approach in managing the Nation's Fisheries. The Council has taken the first step with the submission of the Habitat Plan identifying and describing in detail essential fish habitat (EFH) for species managed throughout the South Atlantic and with the submission of the Comprehensive Habitat Amendment amending all existing FMP's to include descriptions of EFH and EFH-habitat areas of particular concern (EFH-HAPCs). By including an Ecosystems Considerations section in the required SAFE reports, existing data regarding the effects of a fishery on the ecosystem will be provided to the Council on a species by species basis while emphasizing the need for a new level of information. This section will also provide the Assessment Group with a forum in which to express their ecosystem concerns for a specific fishery. In addition to receiving information from the Assessment Group, anecdotal information concerning ecosystem issues has also been gathered through discussions with the Wreckfish Advisory Panel and other people familiar with the fishery and has been included in this section.

While incorporating ecosystem concerns into stock assessment reports is a new approach for this Council, this approach has been taken by the North Pacific Fishery Management Council for several years. A copy of their ecosystems chapter has been included as Appendix E and is an example of the way the ecosystem approach can be used in annual SAFE reports. Another supporting document detailing new ideas and approaches to holistic management is the report to Congress from the Ecosystem Principles Advisory Panel of the NMFS (Appendix F), appointed by the National Academy of Sciences. Congress charged NMFS with establishing this panel to assess the extent that ecosystem principles are used in fisheries management and research and to recommend how such principles can be used to improve our Nation's management of living marine resources.

Ecosystem considerations presented in the interim final rule to implement the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Overview of EFH FMP Amendment Guidelines

The themes of sustainability and risk-averse management are prevalent throughout the Magnuson-Stevens Act, both in the management of fishing practices (e.g., reduction of bycatch and overfishing and consideration of ecological factors in determining optimum yield [OY]) and in the protection of habitats (i.e., prevention of direct and indirect losses of habitats, including EFH). Management of fishing practices and habitat protection are both necessary to ensure long-term productivity of our Nation s fisheries. Mitigation of EFH losses and degradation will supplement the traditional management of marine fisheries. Councils and managers will be able to address a broader range of impacts that may be contributing to the reduction of fisheries resources. Habitats that have been severely altered or impacted may be unable to support populations adequately to maintain sustainable fisheries. Councils should recognize that fishery resources are dependent on healthy ecosystems; and that actions that alter the ecological structure and/or functions within the system can disturb the health or integrity of an ecosystem. Excess disturbance, including over-harvesting of key components (e.g., managed species) can alter ecosystems and reduce their productive capacity. Even though traditional fishery management and FMPs have been *mostly based on yields of single-species or multi-species stocks, these regulations encourage a broader, ecosystem approach to meet the EFH requirements of the Magnuson-Stevens Act. Councils should strive to understand the ecological roles (e.g., prey, competitors, trophic links within food webs, nutrient transfer between ecosystems, etc.) played by managed species within their ecosystems. They should protect, conserve, and enhance adequate quantities of EFH to support a fish population that is capable of fulfilling all of those other contributions that the managed species makes to maintaining a healthy ecosystem as well as supporting a sustainable fishery. Councils must identify in FMPs the habitats used by all life history stages of each managed species in their fishery management units (FMUs). Habitats that are necessary to the species for spawning, breeding, feeding, or growth to maturity will be described and identified as EFH. These habitats must be described in narratives (text and tables) and identified geographically (in text and maps) in the FMP. Mapping of EFH maximizes the ease with which the information can be shared with the public, affected parties, and Federal and state agencies to facilitate conservation and consultation. EFH that is judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation, should be identified as "habitat areas of particular concern" (HAPC) to help provide additional focus for conservation efforts. After describing and identifying EFH, Councils must assess the potential adverse effects of all fishing-equipment types on EFH and must include management measures that minimize adverse effects, to the extent practicable, in FMPs. Councils are also directed to examine non-fishing sources of adverse impacts that may affect the quantity or quality of EFH and to consider actions to reduce or eliminate the effects.*

(ii) EFH determination.
(E) Ecological relationships among species and between the species and their habitat require, where possible, that an ecosystem approach be used in determining the EFH of a managed species or species assemblage. The extent of the EFH should be based on the judgment of the Secretary and the appropriate Council(s) regarding the quantity and quality of habitat that is necessary to maintain a sustainable fishery and the managed species' contribution to a healthy ecosystem.

(11) Review and revision of EFH components of FMPs.
This information should be reviewed as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to § 600.315(e).

4.2. Essential Fish Habitat and Essential Fish Habitat -Habitat Areas of Particular Concern Designations

Essential fish habitat is defined in the Act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The definition for EFH may include habitat for an individual species or an assemblage of species, whichever is appropriate within each FMP.

For the purpose of interpreting the definition of essential fish habitat: "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are utilized by fish. When appropriate this may include areas used historically. Water quality, including but not limited to nutrient levels, oxygen concentration and turbidity levels is also considered to be a component of this definition. Examples of "waters" that may be considered EFH, include open waters, wetlands, estuarine habitats, riverine habitats, and wetlands hydologically connected to productive water bodies.

"Necessary" , relative to the definition of essential fish habitat, means the habitat required to support a sustainable fishery and a healthy ecosystem. While "spawning, breeding, feeding, or growth to maturity" covers a species full life cycle.

In the context of this definition the term "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities. These communities could encompass mangroves, tidal marshes, mussel beds, cobble with attached fauna, mud and clay burrows, coral reefs and submerged aquatic vegetation. Migratory routes such as rivers and passes serving as passageways to and from anadromous fish spawning grounds should also be considered EFH. Included in the interpretation of "substrate" are artificial reefs and shipwrecks (if providing EFH), and partially or entirely submerged structures such as jetties.

The Habitat Plan presents the habitat requirements (by life stage where information exists) for species managed by the Council. Available information on environmental and habitat variables that control or limit distribution, abundance, reproduction, growth, survival, and productivity of the managed species is included.

Essential Fish Habitat for Golden Crab

Essential fish habitat for golden crab includes the U.S. Continental Shelf from Chesapeake Bay south through the Florida Straits (and into the Gulf of Mexico). In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse golden crab larvae. The detailed description of seven essential fish habitat types (a flat foraminferan ooze habitat; distinct mounds, primarily of dead coral; ripple habitat; dunes; black pebble habitat; low outcrop; and soft-bioturbated habitat) for golden crab is provided in Wenner et al. (1987).

Essential Fish Habitat-Habitat Areas of Particular Concern for Golden Crab

There is insufficient knowledge of the biology of golden crabs to identify spawning and nursery areas and to identify HAPCs at this time. As information becomes available, the Council will evaluate such data and identify HAPCs as appropriate through the framework.

4.3 Description of Habitat

Description of the Species and Distribution

The golden crab, *Chaceon fenneri*, is a large gold or buff colored species inhabiting the continental slope of Bermuda (Luckhurst, 1986; Manning and Holthuis, 1986) and the southeastern United States from off Chesapeake Bay (Schroeder, 1959), south through the Straits of Florida and into the eastern Gulf of Mexico (Manning and Holthuis, 1984, 1986; Otwell et al., 1984; Wenner et al., 1987, Erdman 1990).

Reported depth distributions of *C. fenneri* range from 205 m off the Dry Tortugas (Manning and Holthuis, 1984) to 1007 m off Bermuda (Manning and Holthuis, 1986). Size of males examined range from 34 to 139 mm carapace length (CL) and females range from 39 to 118 mm CL. Ovigerous females have been reported during September, October and November, and range in size from 91 to 118 mm CL (Manning and Holthuis, 1984, 1986)."

Larval Distribution & Recruitment

The following text is from Lockhart et al. (1990):

"The distribution patterns of *Chaceon fenneri* and possibly *C. quinquedens* in the eastern Gulf of Mexico suggest a causal role for the Loop Current System (Maul 1977) in basic life history adaptations. Female distribution within these species' geographic ranges and the timing of larval release supports this hypothesis. Ours was the first study to discover female golden crabs in any significant numbers and was also the first to find a major population of female red crabs in the Gulf of Mexico. Both of these concentrations of females were seemingly shifted counter-current to the Loop Current circulation. We hypothesize that this counter-current shift is linked to larval release and transport, and serves to maximize recruitment into the parent population by minimizing risk of larval flushing.

Similar counter-current shifts of other female decapods have been reported or hypothesized. In the Gulf of Mexico, spawning female blue crabs (*Callinectes sapidus*) have been hypothesized to undergo a late summer spawning migration in the northeastern Gulf of Mexico that is counter to the Loop Current system (Oesterling and Adams 1979). Female western rock lobsters (*Panulirus cygnus*) are hypothesized to undergo migration to favor recruitment back into the parent population (Phillips et al. 1979). Kelly et al. (1982) proposed that only those red crab larvae (*Chaceon quinquedens*) released up-current in the species' range will recruit back into the parent population. Melville-Smith (1987a, 1987b, 1987c) in a tagging study of red crabs (*C. maritae*) off the coast of southwest Africa, showed that the only segment of the population exhibiting significant directional movement were adult females: 32% of recaptures had moved greater than 100 km and the greatest distance traveled was 380 km over 5 yr. This directional movement was later shown to be counter to the prevailing surface currents (Melville-Smith 1990). Thus, within decapods in general, and the genus in particular, adult females are capable of, and appear to undergo, long-distance directional movement in their lifetimes.

A similar migration of adult female golden crabs, counter-current to Loop Current circulation in the Gulf of Mexico, would produce the geographic population structure observed off the southeastern United States. Females would be most common farthest up-current whereas males would be most common intermediate in the species geographic range. Wenner et al. (1987) reported a 15:1 (M:F) sex ratio in the South Atlantic Bight and in this study, we had an overall sex ratio of 1:4 — both consistent with hypothesized net female movements to accommodate larval retention and offset the risk of larval flushing.

In fact, given this, two female strategies could maximize recruitment in a prevailing current. The first is for females to position themselves far enough up current so that entrainment would return larvae to the parent population (Sastry 1983). The second is to avoid larval entrainment altogether and thus avoid flushing of the larvae out of the system. Female *Chaceon fenneri*, and perhaps *C. quinquedens*, appear to use both strategies but rely mainly on the latter.

Female golden crabs release larvae offshore in depths usually shallower than 500 m. If larvae were released directly into the Loop Current-Gulf Stream System, they would be entrained for their entire developmental period. Given a developmental time of 33-40 d at 18°C (K. Stuck, Gulf Coast Research Laboratories, Ocean Springs, Mississippi, pers. comm.) and current speeds of 10-20 cm/sec (Sturges and Evans 1983), transport of the larvae would be 285 km to 690 km downstream. Thus, larvae released on the Atlantic side of Florida are in danger of being flushed out of the species' range before recruiting to the benthic stock. Likewise, larvae released directly into the current in the southeastern Gulf of Mexico would be flushed from the Gulf.

Female golden crabs release larvae from February to March (Erdman and Blake 1988; Erdman et al. 1989) and the greatest concentration of female golden crabs to date found in this study was in the northeastern Gulf of Mexico off central Florida. Only during this period and in this region (Maul 1977), can female golden crabs avoid complete entrainment and possible flushing of larvae out of the system. Partial entrainment of larvae might still occur, but its duration should be much reduced, and the risk of larval flushing minimal. This hypothesis predicts that most larvae should be found near the concentrations of females we found in the northeastern Gulf of Mexico with decreasing settlement further downstream. The abundance of juveniles should show a similar pattern.

One need not invoke similar counter-current movements for male geryonid crabs. In particular, males moving perpendicular to adult females (i.e. males moving up and down the continental slope) would have a greater encounter rate with females than males moving along the slope with females. Given low female reproductive frequency (Erdman et al. 1989), intense male-female competition (Lindberg and Lockhart 1988), and probability of multiple broods (Hinsch 1988) from a single protracted copulation (H. M. Perry, pers. obs.), the male strategy should be to intercept relatively rare receptive females all along the species' range, not to aggregate with presumably inseminated females. This hypothesis would predict a relatively uniform abundance of males along their geographic range. In addition, the incidence of inseminated females should be high farthest upstream with an ever decreasing percentage down-stream. Our study supports the former hypothesis but we cannot address the latter.

The distributional patterns of geryonid crabs we observed are consistent with those reported from elsewhere. Furthermore, these patterns lead us to suggest that the Loop Current System has had a causal role in life history adaptations of *Chaceon fenneri* and perhaps *C. quinquedens*. In general, females are expected to release larvae during a time and in a region where risk of larval flushing is minimal (Sinclair 1988), whereas males are expected to compete intensely for rare, receptive mates."

The coastal physical oceanography in the Florida Keys was described by Yeung (1991) in a study of lobster recruitment:

"The strong, northward-flowing Florida Current is the part of the Gulf Stream system confined within the Straits of Florida. It continues from the Loop Current in the Gulf of Mexico, and proceeds beyond Cape Hatteras as the North Atlantic Gulf Stream.

The mean axis of the Florida Current is approximately 80 km offshore of Key West and 25 km off Miami (Lee et al. 1991). Mean annual cross-stream surface current speed in the Straits of Florida is approximately 100 cm/s (U.S. Naval Oceanographic Office 1965).

Brooks and Niller (1975) observed a persistent countercurrent near Key West extending from surface to the bottom, and from nearshore to approximately 20 km seaward. They believed that it was part of the cyclonic recalculation of the Florida Current between the Lower and Middle Keys.

The presence of a cold, cyclonic gyre was confirmed by physical oceanographic data collected in the SEFCAR cruises. It was named the Pourtales Gyre since it occurs over the Pourtales Terrace -- that area of the continental shelf off the Lower and Middle Keys (Lee et al. 1991). When the Florida Current moves offshore, the Pourtales Gyre forms over the Pourtales Terrace, and can last for a period of 1-4 weeks.

The Pourtales Gyre could entrain and retain locally spawned planktonic larvae for a short period. The combination of the cyclonic circulation and enhanced surface Ekman transport could also advect foreign arrivals into, and concentrate them at, the coastal boundary (Lee et al. 1991).

Vertical distribution of the larvae within the 3-dimensional circulation will subject them to complicated hydrographic gradients, which might influence their development time, and hence their dispersal potential (Kelly, Sulkin, and van Heukelem 1982; Sulkin and McKeen 1989). Thus, variability in the circulation features and water mass properties can lead to variability in larval transport and recruitment."

The Pourtales Gyre may provide a mechanism for entrainment of golden crab larvae spawned on the Florida east coast, and also as a mechanism to entrain and advect larvae from the Gulf and Caribbean (e.g., Cuba). This possibility is supported by the conclusion of Yeung (1991) suggesting that larvae of a foreign origin supply recruits to the Florida spiny lobster population:

"The foreign supply of pre-recruits arriving with the Florida Current might easily meet the same fate as the locally spawned larvae, that is, passing on with the Florida Current. The Pourtales Gyre may play a significant role in recruitment by providing a physical mechanism to entrain and advect larvae into the coastal boundary.

The Pourtales Gyre, even if linked with the Dry Tortugas gyre or the Florida Bay circulation, may not be able to provide a pathway much more than 2 months in period. For locally spawned *Panulirus* larvae to be retained for their entire development would require several circuits -- not impossible, but unlikely"

The timing of the Pourtales Gyre provides a mechanism for local recruitment of *Scyllarus* larvae (Yeung, 1991) and may also provide a similar mechanism for golden crab larvae. Golden crab larvae from the Gulf of Mexico, Cuba, and possibly other areas of the Caribbean, probably provide larvae to the South Atlantic population. The proportion of local recruitment is unknown but could be significant.

Feeding

Feeding habits are very poorly known. Golden crabs are often categorized as scavengers that feed opportunistically on dead carcasses deposited on the bottom from overlying waters (Hines, 1990).

Movement

Wenner et al. (1987) found in the South Atlantic Bight that: " Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migrations such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al., 1982)."

Lindberg and Lockhart (1993) found in the Gulf of Mexico: " The golden crab *Chaceon fenneri* in the eastern Gulf of Mexico exhibits a typical bathymetric pattern of partial sex zonation and an inverse size-depth relationship, as first reported for red crabs (*C. quinquedens*: Wigley et al., 1975; *C. maritae*: Beyers and Wilke, 1980). Sex segregation, with females shallower than most males, was more evident in our results than in those of Wenner et al. (1987) from the South Atlantic Bight, primarily because our trap catch had a higher proportion of females (25.9% compared to 5.2%)."

Abundance

Golden crab abundance studies are limited. Data from the South Atlantic Bight (Wenner et al., 1987) estimated abundance from visual assessment was 1.9 crabs per hectare while traps caught between 2 and 10 kg per trap. Wenner and Barans (1990) estimated the golden crab population in small areas of 26-29 square km between 300-500 m off Charleston to be 5,000-

6,000 adult crabs. In the eastern Gulf of Mexico adult standing stock was estimated to be 7.8 million golden crabs and the biomass was estimated to be 6.16 million kg (13.6 million pounds) (Lindberg et al., 1989). Experimental trapping off Georgia yielded an average catch of 7 kg per trap (Kendall, 1990).

Habitats Identified in the Habitat Plan Which Constitute the Ecosystem Used by Managed Species including Golden Crab

A. Marine/Offshore Essential Fish Habitat

Marine offshore habitats include live/hard bottom, coral and coral reefs, artificial/manmade reefs, pelagic *Sargassum* and water column habitat. Section 3.2 presents individual detailed descriptions including species use of these habitats.

Live/Hard Bottom Habitat

Major fisheries habitats on the Continental Shelf along the southeastern United States from Cape Hatteras to Cape Canaveral (South Atlantic Bight) can be stratified into five general categories: coastal, open shelf, live/hard bottom, shelf edge, and lower shelf based on type of bottom and water temperature. Each of these habitats harbors a distinct association of demersal fishes (Struhsaker 1969) and invertebrates. The description of this essential fish habitat presented in Section 3.2.1.2, segregates the region into two sections: a) Cape Hatteras to Cape Canaveral; and b) Cape Canaveral to the Dry Tortugas. These regions represent temperate, wide-shelf systems and tropical, narrow-shelf systems, respectively. The zoogeographic break between these regions typically occurs between Cape Canaveral and Jupiter Inlet.

Covered by a vast plain of sand and mud underlain at depths of less than a meter by carbonate sandstone is relatively unattractive to fish. Live/hard bottom, usually found near outcropping shelves of sedimentary rock in the zone from 15 to 35 fathoms and at the shelf break, a zone from about 35 to 100 fathoms where the Continental Shelf adjoins the deep ocean basin and is often characterized by steep cliffs and ledges. The live bottom areas constitute essential habitat for warm-temperate and tropical species of snappers, groupers, and associated fishes including 113 species of reef fish representing 43 families of predominately tropical and subtropical fishes off the coasts of North Carolina and South Carolina.

The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2. These geographic coverage's are a compilation of the four state bottom mapping effort in the South East Monitoring and Assessment Program (SEAMAP). The Florida Marine Research Institute developed uniform ArcView coverage's of hard bottom habitat (including coral, coral reefs, live/hard bottom, and artificial reefs) as a 1998 SEAMAP program and provided it to the Council for inclusion into the south Atlantic essential fish habitat distribution data base and GIS system.

Coral and Coral Reefs

Coral reef communities or solitary specimens exist throughout the south Atlantic region from nearshore environments to continental slopes and canyons, including the intermediate shelf zones. Habitats supporting corals and coral-associated species are discussed below in groupings based on their physical and ecological characteristics. Dependent upon many variables, corals may dominate a habitat, be a significant component, or be individuals within a community characterized by other fauna. Geologically and ecologically, the range of coral assemblages and habitat types is equally diverse. The coral reefs of shallow warm waters are typically, though not always, built upon coralline rock and support a wide array of hermatypic and ahermatypic corals, finfish, invertebrates, plants, and microorganisms. Hard bottoms and hard banks, found on a wider bathymetric and geographic scale, often possess high species diversity but may lack hermatypic corals, the supporting coralline structure, or some of the associated biota. In deeper waters, large elongate mounds called deepwater banks, hundreds of meters in length, often support a rich fauna compared to adjacent areas. Lastly are communities including solitary corals. This category often lacks a topographic relief as its substrate, but instead may use a sandy bottom, for example. Coral habitats (i.e., habitats to which coral is a significant contributor) are divided into five categories - solitary corals, hard bottoms, deepwater banks, patch reefs, and outer bank reefs. The order of presentation approximates the ranking of habitat complexity based upon species diversity (e.g., zonation, topographic relief, and other factors). Although attempts have been made to generalize the discussion into definable types, it must be noted that the continuum of habitats includes many more than these five distinct varieties.

The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.1.2. The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2.

Water Column

Specific habitats in the water column can best be defined in terms of gradients and discontinuities in temperature, salinity, density, nutrients, light, etc. These "structural" components of the water column environment are not static, but change both in time and space. Therefore, there are numerous potentially distinct water column habitats for a broad array of managed species and life-stages within species.

The discussion of the ecological function of water column habitat and importance to managed species is presented in Section 3.2.3.2.

Detailed Golden Crab Habitat Description

Based on exploratory trapping, golden crab maximum abundance occurs between 367 and 549 meters in the South Atlantic Bight. Information on sediment composition suggest that golden crab abundance is influenced by sediment type with highest catches on substrates containing a mixture of silt-clay and foraminiferan shell. Wenner et al. (1987) further notes: "Other studies have described an association of *G. quinquedens* with soft substrates. Wigley et al. (1975) noted that bottom sediments throughout the area surveyed for red crab from offshore Maryland to Corsair Canyon (Georges Bank) consisted of a soft, olive-green, silt-clay mixture. If golden crabs preferentially inhabit soft substrates, then their zone of maximum abundance may be limited within the South Atlantic Bight. Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270-450 m between St. Augustine and Cape Canaveral, FL (30°N and 28°N). This same depth range from Savannah, GA to St. Augustine was generally characterized by Bullis and Rathjen (1959) as extremely irregular bottom with some smooth limestone or "slab" rock present. Our study indicates, however, that the bottom due east between Savannah and St. Catherines Island, GA at 270-540 m consists of mud and biogenic ooze. Further north from Cape Fear, NC to Savannah, bottom topography between 270 and 450 m is highly variable with rocky outcrops, sand and mud ooze present (Low and Ulrich, 1983)."

In a subsequent study using a submersible, Wenner and Barans (1990) found the greatest abundance in rock outcrops:

Observations on density and a characterization of essential habitat for golden crab, *Chaceon fenneri*, were made from a submersible along 85 transects in depths of 389-567 m approximately 122 km southeast of Charleston, South Carolina. Additional observations on habitat were made on 16 transects that crossed isobaths between 293-517 m.

Seven essential habitat types can be identified for golden crab from observations:

- A flat foraminiferon ooze habitat (405-567 m) was the most frequently encountered habitat. This habitat type is characterized by pteropod-foraminiferan debris mixed with larger shell fragments, a sediment surface mostly covered with a black phosphorite precipitate;

- Distinct mounds, primarily of dead coral at depths of 503 to 555 meters and constituted 20% of the bottom surveyed on dives to count crabs. Coral mounds rose approximately 15 to 23 meters in height above the surrounding sea floor and included several that were thinly veneered with a fine sediment and dead coral fragments, as well as a number that were thickly encrusted with live branching ahermatypic corals (*Lophelia prolifera* and *Enallopsammia profunda*). Fan-shaped sponges, pennatulids and crinoids were oriented into the northerly 1.4-1.9 km- h^{-1} current. The decapod crustaceans *Bathynectes longispina*, *Heterocarpus ensifer* and *Eumunida pita*, the black-bellied rosefish, *Helicolenus dactylopterus*, and the wreckfish, *Polyprion americanus*, were frequently sighted along transects in the coral mound habitat.

- Ripple habitat (320-539 m); dunes (389-472 m); black pebble habitat (446-564 m); low outcrop (466-512 m); and soft-bioturbated habitat (293-475 m). A total of 109 *C. fenneri* were sighted within the 583,480 m^2 of bottom surveyed. Density (mean no. per 1,000 m^2) was significantly different among habitats, with highest values (0.7 per 1,000 m^2) noted among low rock outcrops. Lowest densities were observed in the dune habitat (<0.1 per 1,000 m^2), while densities for other habitats were similar (0.15-0.22 per 1,000 m^2)."

A similar submersible study in the eastern Gulf of Mexico (Lindberg and Lockhart, 1993) found similar results with higher abundance on hard bottom: "Within the bathymetric range of golden crabs, crab abundance may be related more to habitat type than to depth. The greatest density (36.5 crabs/ha) occurred on or near hard-bottom canyon features."

Golden crab occupy offshore oceanic waters along the Atlantic and Gulf of Mexico coasts as adults. Offshore areas used by adults are probably the least affected by habitat alterations and water quality degradation. Currently, the primary threat comes from oil and gas development and production, offshore dumping of dredged material, disposal of chemical and other wastes, and the discharge of contaminants by river systems.

4.4 The Effects of Fishing Gear on the Ecosystem and Prior Council Action

Pursuant the guidelines implementing the essential fish habitat provisions of the Magnuson-Stevens Act, conservation and enhancement measures implemented by the Council may include ones that eliminate or minimize physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. The Council has implemented restrictions on fisheries to the extent that no significant activities were identified in the review of gear impact conducted for the NMFS by Auster and Langton (1998) that presented available information on adverse effects of all fishing equipment types used in waters described as EFH. The Council has already prevented, mitigated, or minimized most adverse effects from most fisheries prosecuted in the South Atlantic EEZ.

The Council considered evidence that some fishing practices are having an identifiable adverse effect on habitat, and addressed these in the comprehensive habitat amendment. The Council has already used many of the options recommended in the essential fish habitat guidelines for managing adverse effects from fishing including: fishing equipment restrictions; seasonal and aerial restrictions on the use of specified equipment; equipment modifications to allow the escape of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting equipment in sensitive areas; prohibitions on fishing activities that cause significant physical damage in EFH; time/area closures including closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern; and harvest limits.

More specifically, the Council has protected habitat essential to managed species by regulating fisheries to reduce or eliminate the direct or indirect impacts of fishing. With the implementation of the Coral Fishery Management Plan and subsequent amendments to that plan, the Council has protected coral, coral reefs, and live/hard bottom habitat in the south Atlantic region by establishing an optimum yield of zero and prohibiting all harvest or possession of these resources which serve as essential fish habitat to many managed species. Another measure adopted by the Council and implemented through the coral plan was the designation of the Oculina Bank Habitat Area of Particular Concern, a unique and fragile deepwater coral habitat off southeast Florida that is protected from all bottom tending fishing gear damage. The Council has also prohibited the use of the following gears in the snapper grouper fishery management plan to protect habitat: bottom longlines in the EEZ inside of 50 fathoms or anywhere south of St. Lucie Inlet Florida, fish traps, bottom tending (roller-rig) trawls on live bottom habitat, and entanglement gear. Also established under the snapper grouper plan is an Experimental Closed Area (experimental marine reserve) where the harvest or possession of all species in the snapper grouper complex is prohibited. Other actions taken by the Council that directly or indirectly protect habitat or ecosystem integrity include: the prohibition of rock shrimp trawling in a designated area around the Oculina Bank, mandatory use of bycatch reduction devices in the penaeid shrimp fishery, a prohibition of the use of drift gill nets in the coastal migratory pelagic fishery; and a mechanism that provides for the concurrent closure of the EEZ to penaeid shrimping if environmental conditions in state waters are such that the overwintering spawning stock is severely depleted.

4.5 Endangered Species and Marine Mammal Acts

The Sustainable Fisheries Act of 1996 established certain requirements and standards the Councils and the Secretary must meet in managing fisheries under the Magnuson-Stevens Act. Implementing the provisions in the SFA will not have any negative impacts on the listed and protected species under the Endangered Species Act (ESA) and Marine Mammals Protection Act (MMPA) including:

	Whales:	Date Listed
(1)	Northern right whale- *Eubalaena glacialis* (ENDANGERED)	12/2/70
(2)	Humpback whale- *Magaptera novaeangliae* (ENDANGERED)	12/2/70
(3)	Fin whale- *Balaenoptera physalus* (ENDANGERED)	12/2/70
(4)	Sei whale- *Balaenoptera borealis* (ENDANGERED)	12/2/70
(5)	Sperm whale- *Physeter macrocephalus* (ENDANGERED)	12/2/70
(6)	Blue whale- *Balaenoptera musculus* (ENDANGERED)	

	Sea Turtles:	Date Listed
(1)	Kemp's ridley turtle- *Lepidochelys kempii* (ENDANGERED)	12/2/70
(2)	Leatherback turtle- *Dermochelys coriacea* (ENDANGERED)	6/2/70
(3)	Hawksbill turtle- *Eretmochelys imbricata* (ENDANGERED)	6/2/70
(4)	Green turtle- *Chelonia mydas* (THREATENED/ENDANGERED)	7/28/78
(5)	Loggerhead turtle- *Caretta caretta* (THREATENED)	7/28/78

	Other Species Under U.S. Fish and Wildlife Service Jurisdiction:	Date Listed
(1)	West Indian manatee- *Trichechus manatus* (ENDANGERED)	3/67
	(Critical Habitat Designated)	1976
(2)	American crocodile - *Crocodulus acutus* (ENDANGERED)	9/75
	(Critical Habitat Designated)	12/79

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<u>Golden Crab Advisory Panel:</u>
Richard Nielsen, Jr., Chairman
Tim Daniels
Eddy Owl
William Whipple
Gary Graves, Vice Chairman
Richard (Dick) Nielsen, Sr.
Howard Rau, Jr.

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SAFMC. 1995. Fishery Management Plan (Including Regulatory Impact Review, Environmental Assessment, and Social Impact Assessment) for the Golden Crab Fishery of the South Atlantic Region. December 1995. Prepared by the South Atlantic Council, 1 Southpark Circle, Suite 306, Charleston, South Carolina 29407.

7.0 APPENDICES

Appendix A. Results of Literature Search For Golden Crab

TI: Title
The golden crab (Geryon fenneri) fishery of Southeast Florida.
AU: Author
Erdman, RB; Blake, NJ
AF: Author Affiliation
Dep. Mar. Sci., Univ. South Florida, St. Petersburg, FL 33701, USA
CA: Corporate Author
Florida Univ., Gainesville (USA). Sea Grant Coll. Program
CF: Conference
12. Annual Conference of the Tropical and Subtropical Fisheries Technological Society of the Americas, Orlando, FL (USA), 9-11 Nov 1987
SO: Source
PROCEEDINGS: TWELFTH ANNUAL CONFERENCE OF THE TROPICAL AND SUBTROPICAL FISHERIES TECHNOLOGICAL SOCIETY OF THE AMERICAS., 1988, pp. 95-106, REP. FLA. SEA GRANT COLL. PROGRAM.
NU: Other Numbers
FSGR-92
AB: Abstract
Because of marketing problems compounded by distances > 100 miles to the fishing grounds, gear loss and the absence of information on the distribution and biology of this species, commercial golden crab operations in the eastern Gulf of Mexico ceased by mid-1985. In February 1986, the authors began a study of the biology of Geryon fenneri as collected from this southeast Florida fishery. Reproductive biology, size and weight relationships, trap design and catch per unit effort were examined to ascertain additional information relative to the study of this potentially valuable species.

TI: Title
Reproductive ecology of female golden crabs, Geryon fenneri Manning and Holthuis, from southeastern Florida.
AU: Author
Erdman, RB; Blake, NJ
AF: Author Affiliation
Dep. Mar. Sci., Univ. South Florida, 140 7th Ave. South, St. Petersburg, FL 33701, USA
SO: Source
Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 8, no. 3, pp. 392-400, 1988
IS: ISSN
0278-0372
AB: Abstract

Examination of deep-water female golden crabs collected monthly from the southeastern coast of Florida indicates an annual reproductive cycle with a single batch of eggs produced each year. Oviposition begins in late August and continues through October with eggs retained for approximately 6 months until hatching during late February and March. Sizes of ovigerous females examined ranged from 96 to 147 mm carapace width (CW). Extruded eggs averaged 540 mu m in diameter, increasing to between 580 and 600 mu m prior to hatching. Fecundity estimates range from 131,000 to 347,000 eggs with brood size highly correlated to CW. Changes in gonopore margins associated with molting and the onset to ovarian activity indicated that size at sexual maturity is between 85 and 100 mm CW. Although sampling depth ranges were limited, Geryon fenneri may display similar segregation by sex and size depth as other species of Geryon .

TI: Title
Comparative reproduction of the deep-sea crabs Chaceon fenneri and C. quinquedens (Brachyura: Geryonidae) from the northeast Gulf of Mexico.
AU: Author
Erdman, RB; Blake, NJ; Lockhart, FD; Lindberg, WJ; Perry, HM; Waller, RS
AF: Author Affiliation
Florida Inst. Oceanogr., 830 1st St. S., St. Petersburg, FL 33701, USA
SO: Source
Invertebrate reproduction and development. Rehovot [INVERTEBR. REPROD. DEV.], vol. 19, no. 3, pp. 175-184, 1991
IS: ISSN
0168-8170
AB: Abstract
Northeastern Gulf of Mexico populations of deep-sea golden crabs (Chaceon fenneri) and red crabs (C. quinquedens) were sampled quarterly from May 1987 through February 1988 to examine the timing of reproductive events. C. fenneri was most abundant at sample depths between 311 and 494 m while C. quinquedens showed a minimum depth of occurrence of 677 m. Both species exhibited an annual reproductive cycle with a distinct winter brooding period. However, oviposition in C. quinquedens began in May, approximately three months earlier than in C. fenneri ; consequently the single batch of eggs produced were brooded for nine months in C. quinquedens and six months in C. fenneri . Larvae of both species hatched during February and March of the following year. Differences in the duration of reproductive events may reflect the segregated bathymetric distribution of each species. The incidence of molting females and non-ovigerous females observed during the

fall-winter brooding period suggests that although both species reproduce annually on the population level, individuals may reproduce biennially. This low frequency of reproduction may be a consequence of the reduced food supply characteristic of the continental slope environment.

TI: Title
Oxygen consumption of the deep-sea crabs Chaceon fenneri and C. quinquedens (Brachyura: Geryonidae).
AU: Author
Erdman, RB; Blake, NJ; Torres, JJ
AF: Author Affiliation
Dep. Mar. Sci., Univ. South Florida, 140 7th Ave. S., St. Petersburg, FL 33701, USA
SO: Source
Comparative Biochemistry and Physiology, A [COMP. BIOCHEM. PHYSIOL., A.], vol. 99A, no. 3, pp. 383-385, 1991
IS: ISSN
0300-9629
AB: Abstract
Oxygen consumption rates (VO sub(2)) were determined for the deep-sea crabs Chaceon fenneri) and C. quinquedens , two important members of the continental slope megafauna in the eastern Gulf of Mexico. The VO sub(2) of C. fenneri) declined from 0.014 ml O sub(2)/g/hr at 12 degree C to 0.010 ml O sub(2)/g/hr at 6 degree C; VO sub(2) of C. quinquedens) showed a decline from 0.012 ml O sub(2)/g/hr to 0.008 ml O sub(2)/g/hr over the same temperature range. The VO sub(2) of C. fenneri) and C. quinquedens are comparable to those of similar size shallow water decapod crustaceans that inhibit equivalent temperatures. The oxygen consumption rates of C. fenneri and C. quinquedens decline with increasing depth of occurrence purely as a function of temperature.

TI: Title
Physiology of two species of deep-water crabs, Chaceon fenneri and C. quinquedens ; Gill morphology, and hemolymph ionic and nitrogen concentrations.
AU: Author
Henry, RP; Perry, HM; Trigg, CB; Handley, HL; Krarup, A
AF: Author Affiliation
Dep. Zool. Wildl. Sci. and Alabama Agric. Exp. Stn., 101 Cary Hall, Auburn Univ., Auburn, AL 36849-5414, USA
SO: Source
Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 10, no. 3, pp. 375-381, 1990
IS: ISSN

0278-0372

AB: Abstract

The general physiology of two spp. of deep-water crabs, Chaceon fenneri and C. quinquedens , found in thermally stable environments at moderate depths, was investigated. Structure-function relationships of the gills indicate animals that are typical of environments characterized by high and stable salinity. The gill lamellae are composed entirely of respiratory epithelium; no ion-transporting "chloride cells" were observed. Carbonic anhydrase, a marker enzyme for ion transport in the gill, was present in very low levels of activity, and blood osmotic and ionic concentrations were not different from ambient at salinities of either 35 or 20 ppt. Animals failed to survive in salinities < 20 ppt. Oxygen uptake values were typical of cold-water, benthic species, regardless of habitat depth. C. quinquedens appears to have both a higher rate of oxidative metabolism and a higher rate of protein metabolism than C. fenneri , which may be indicative of a higher rate of growth. Both spp., however, appear to be physiologically similar to stenohaline marine decapods from cold, shallow-water habitats.

TI: Title

Respiratory and cardiovascular responses of two species of deep-sea crabs, Chaceon fenneri and C. quinquedens , in normoxia and hypoxia.

AU: Author

Henry, RP; Handley, HL; Krarup, A; Perry, HM

AF: Author Affiliation

Dep. Zool. and Wildl. Sci., 101 Cary Hall, Auburn Univ., Auburn, Al 36849-5414, USA

SO: Source

Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 10, no. 3, pp. 413-422, 1990

IS: ISSN

0278-0372

AB: Abstract

The respiratory and cardiovascular variables in Chaceon fenneri and C. quinquedens were examined in animals during normoxia, animals exposed to hypoxia, and animals allowed to recover in normoxia. C. fenneri was characterized by a relatively low metabolic rate (low oxygen uptake), and low ventilatory frequency. This species displayed a pattern of oxy-independent O sub(2) uptake when exposed to hypoxia: MO sub(2) was maintained primarily through hyperventilation. At an environmental PO sub(2) of about 25 torr, respiratory and cardiovascular functions shut down, and the animal appeared to make the transition to exclusively anaerobic energy production. Oxygen uptake in resting C.

quinquedens) was roughly double that in C. fenneri and ventilatory frequency was 3-fold higher. MO sub(2) declined in hypoxia and hyperventilation was absent, a more typical oxy-dependent pattern of respiration. The ambient PO sub(2) at which ventilatory and cardiovascular shutdown occurred was about 17 torr, but oxygen uptake continued at very low levels even in severe hypoxia.

TI: Title
Fecundity and reproductive output in two species of deep-sea crabs, Geryon fenneri and G. quinquedens (Decapoda: Brachyura).
AU: Author
Hines, AH
AF: Author Affiliation
Smithsonian Environ. Res. Cent., P.O. Box 28, Edgewater, MD 21037, USA
SO: Source
Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 8, no. 4, pp. 557-562, 1988
IS: ISSN
0278-0372
AB: Abstract
Brood weight, fecundity, and egg size as a function of female body size were compared in the deep-sea red crab Geryon quinquedens and the deep-sea golden crab Geryon fenneri . Females of G. fenneri attained a larger body size then G. quinquedens , and body size in both species was the main determinant of reproductive output (brood mass) and fecundity per brood. Both species differed from most other brachyurans in having larger reproductive outputs, larger eggs, and lower fecundities relative to their large body sizes. After statistical adjustment for differences in body size between the two species, G. quinquedens had space in the body cavity for yolk accumulation and a brood mass which were 50% larger than G. fenneri .

TI: Title
Morphology of the reproductive tract and seasonality of reproduction in the golden crab Geryon fenneri from the eastern Gulf of Mexico.
AU: Author
Hinsch, GW
AF: Author Affiliation
Dep. Biol., Univ. South Florida, Tampa, FL 33620, USA
SO: Source
Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 8, no. 2, pp. 254-261, 1988
IS: ISSN
0278-0372

AB: Abstract

Reproduction and anatomy of the reproductive tracts of males and females of the golden crab Geryon fenneri were studied for one year (1984-1985) in specimens collected from deep water of the eastern Gulf of Mexico. The male crab is larger than the female. Their reproductive tracts are typical of brachyurans.

TI: Title

Ultrastructure of the sperm and spermatophores of the golden crab Geryon fenneri and a closely related species, the red crab G. quinquedens , from the eastern Gulf of Mexico.

AU: Author

Hinsch, GW

AF: Author Affiliation

Dep. Biol., Univ. South Florida, Tampa, FL 33620, USA

SO: Source

Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 8, no. 3, pp. 340-345, 1988

IS: ISSN

0278-0372

AB: Abstract

The sperm of species of Geryon are typical of brachyurans in having a complex acrosome, a membranous lamellar complex, uncondensed chromatin in the nucleus, and nuclear arms or spikes of varying lengths. There are no microtubular elements in the arms. The spermatophores are ellipsoidal or round and contain varying numbers of sperm. The wall of each spermatophore is two-layered and fairly impermeable to fixatives. Globules of seminal fluid surround the spermatophores in the vasa deferentia.

TI: Title

Spatial patterns of abundance for deep-water golden crab (Geryon fenneri) and red crab (G. quinquedens) in the eastern Gulf of Mexico.

AU: Author

Lindberg, WJ; Lockhart, F; Perry, H; Waller, R

AF: Author Affiliation

Dep. Fish. and Aquacult., Univ. Florida, 7922 N.W. 71st St., Gainesville, FL 32606, USA

CA: Corporate Author

Florida Univ., Gainesville (USA). Sea Grant Coll. Program

CF: Conference

12. Annual Conference of the Tropical and Subtropical Fisheries Technological Society of the Americas, Orlando, FL (USA), 9-11 Nov 1987

SO: Source

PROCEEDINGS: TWELFTH ANNUAL CONFERENCE OF THE TROPICAL AND SUBTROPICAL FISHERIES TECHNOLOGICAL SOCIETY OF THE AMERICAS., 1988, p. 671, REP. FLA. SEA GRANT COLL. PROGRAM.

NT: Notes
Abstract only.

NU: Other Numbers
FSGR-92

AB: Abstract
Submersible transects and trap sampling confirmed concentrations of golden crabs (Geryon fenneri) (1) along intermediate depth contours, associated with rock outcroppings, and (2) off peninsular Florida rather than the northern Gulf. Red crabs (Geryon quinquedens) were deeper and at northern as well as southern stations. Both species showed sex differences in distribution.

TI: Title
Geryonid crabs and associated continental slope fauna: A research workshop report.

AU: Author
Lindberg, WJ; Wenner, EL

CA: Corporate Author
Florida Sea Grant Coll. Program, Gainesville, (USA)

SO: Source
TECH. PAP. FLA. SEA GRANT PROGRAM., 1990, 74 pp

NT: Notes
NTIS Order No.: PB90-190620/GAR.

NU: Other Numbers
FSG-TP-58

AB: Abstract
Considerable research in recent years has been invested in the basic biology, ecology, and fisheries of deep-water crabs. Family Geryonidae. These efforts have been concentrated off the southeastern United States and southwest Africa, following earlier work from the Mid-Atlantic states of the U.S. to the Canadian Maritime Provinces. Species of primary interest have been the golden crab, Chaceon fenneri , and the red crabs Chaceon maritae and Chaceon quinquedens . On January 19 and 20, 1989, an invited panel of scientists, fishermen, and Sea Grant Extension faculty met in Tampa, Florida to share their results, conclusions, and latest hypotheses. (Grant NA86AA-D-SG068. Prepared in cooperation with South Carolina Sea Grant Consortium, Charleston. Sponsored by Marine Resources Research Inst., Charleston, SC., and National Undersea Research Program, Groton, CT.)

TI: Title
Depth-stratified population structure of geryonid crabs in the

eastern Gulf of Mexico

AU: Author

Lindberg, WJ; Lockhart, FD

AF: Author Affiliation

Dep. Fish. Aquat. Sci., Univ. Florida, 7922 NW 71st St., Gainesville, FL 32606, USA

SO: Source

Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 13, no. 4, pp. 713-722, 1993

IS: ISSN

0278-0372

AB: Abstract

Manned submersible transects and synchronous trap-sampling were conducted in the eastern Gulf of Mexico along 5 depth contours on the upper continental slope, during September 1986 and 1987. Female golden crabs, Chaceon fenneri, were more abundant at 350 m and 445 m than at 550, 675, or 780 m. Male golden crabs were most abundant at 550 m. On the average, the largest crabs of each sex were caught near 350 m. More mated pairs (50%) were observed in situ along the deepest 2 contours than expected by chance alone. Within the bathymetric range of golden crabs, crab abundance may be related more to habitat type than to depth. The greatest density (36.5 crabs/ha) occurred on or near hard-bottom canyon features. Red crabs, Chaceon quinquedens, occurred only at 675 m and 780 m on heavily bioturbated soft sediments, with the largest of each sex at 675 m. Male red crabs outnumbered females, but depth did not affect the number caught. Golden and red crabs also differed in their refuging habits and responses to being disturbed. We suggest that bathymetric patterns in sex and size within geryonid populations reflect, in part, severe male-male competition for mates and alternative mating strategies for males.

TI: Title

Distributional differences and population similarities for two deep-sea crabs (family Geryonidae) in the northeastern Gulf of Mexico.

AU: Author

Lockhart, FD; Lindberg, WJ; Blake, NJ; Erdman, RB; Perry, HM; Waller, RS

AF: Author Affiliation

Dep. Fish. Aquacult., Univ. Florida, 7922 N.M. 71 St., Gainesville, FL 32606, USA

SO: Source

Canadian Journal of Fisheries and Aquatic Sciences [CAN. J. FISH. AQUAT. SCI.], vol. 47, no. 11, pp. 2112-2122, 1990

IS: ISSN

0706-652X

NT: Notes
Incl. bibliogr.: 37 ref.
AB: Abstract
For golden crab, Chaceon fenneri , and red crab, Chaceon quinquedens , numbers per trap, sex, and crab size were tested for broad bathymetric, geographic, and seasonal patterns on the upper continental slope, northeastern Gulf of Mexico. Red crab occupied only the deepest of three sampled depths (i.e. 677 m vs. 494 and 311 m) while golden crab predominated at the upper two. Golden crab occurred adjacent to peninsular Florida, but not along the northern Gulf slope, while red crab occurred across the geographic arc sampled. Relative abundance increased southward for golden crab and northwestward for red crab, while the proportion of females increased counter-clockwise within the sampled range of each species.

TI: Title
Discovery of deep-water crabs (Geryon spp.) at Bermuda - a new potential fishery resource.
AU: Author
Luckhurst, B
AF: Author Affiliation
Div. Fish., P.O. Box 622, Southampton 8, Bermuda
CF: Conference
37. Annual Gulf and Caribbean Fisheries Institute, Cancun (Mexico), Nov 1984
ED: Editor
Williams, F (ed)
SO: Source
PROCEEDINGS OF THE THIRTY-SEVENTH ANNUAL GULF AND CARIBBEAN FISHERIES INSTITUTE, CANCUN, MEXICO, NOVEMBER, 1984., 1986, pp. 209-211, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], vol. 37
IS: ISSN
0072-9019
NU: Other Numbers
GCFI-37
AB: Abstract
The discovery of two species of deep water crabs (Geryonidae) at Bermuda in 1984 is documented. The first species is Geryon fenneri while the second, smaller species is undescribed. Preliminary data on the size frequency distribution of G. fenneri as well as the sex ratio and presence of ovigerous females is presented. In July 1984, a local trap fisherman John P. (Sean) Ingham set a small number of traps off the edge of the Bermuda platform to do some exploratory fishing. These traps yielded two different species of Geryon crabs one of which is presently fished commercially in the

Gulf of Mexico. This finding prompted further investigation to determine the extent of the resource and the possible development of a small, specialized fishery.

TI: Title
Notes on Geryon from Bermuda, with the description of Geryon inghami , new species (Crustacea: Decapoda: Geryonidae).
AU: Author
Manning, RB; Holthuis, LB
AF: Author Affiliation
Dep. Invertebr. Zool., Natl. Mus. Nat. Hist., Smithsonian Inst., Washington, DC 20560, USA
SO: Source
Proceedings of the Biological Society of Washington. Washington DC [PROC. BIOL. SOC. WASH.], vol. 99, no. 2, pp. 366-373, 1986
IS: ISSN
0006-324X
AB: Abstract
Two species of the deep water crab genus Geryon , taken in commercial traps, G. fenneri Manning and Holthuis and G. inghami , n. sp., are reported from Bermuda. Geryon incertus Miers, 1886, originally described from Bermuda, is shown to be a junior synonym of the portunid Bathynectes longispina Stimpson, 1871.

TI: Title
Size and weight relationships for the golden crab, Chaceon fenneri, and the red crab, Chaceon quinquedens, from the eastern Gulf of Mexico
AU: Author
Trigg, C; Perry, H; Brehm, W
AF: Author Affiliation
Gulf Coast Res. Lab., Ocean Springs, MS 39564-7000, USA
SO: Source
Gulf Research Reports [GULF RES. REP.], vol. 9, no. 4, pp. 339-343, Jan 1997
IS: ISSN
0072-9027
AB: Abstract
Carapace length, carapace width, and weight relationships are discussed for the golden crab, Chaceon fenneri, and the red crab, Chaceon quinquedens, from the eastern Gulf of Mexico. Males of both species were significantly larger than females in comparisons of means of all measured parameters. Relationships between carapace length and carapace width, carapace length and weight, and carapace width and weight were similar between Atlantic and

Gulf of Mexico populations for both species.

TI: Title
Activities of metabolic enzymes in the deep-water crabs Chaceon fenneri and C. quinquedens and the shallow-water crab Callinectes sapidus .
AU: Author
Walsh, PJ; Henry, RP
AF: Author Affiliation
Div. Mar. Biol. and Fish., Rosenstiel Sch. Mar. and Atmos. Sci., Univ. Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
SO: Source
Marine biology. Berlin, Heidelberg [MAR. BIOL.], vol. 106, no. 3, pp. 343-346, 1990
IS: ISSN
0025-3162
AB: Abstract
The activities of 18 enzymes were measured in gill, hepatopancreas and muscle tissue of the deep-water crabs Chaceon fenneri and C. quinquedens and the shallow-water crab Callinectes sapidus collected from the low-water crab Callinectes sapidus collected from the Gulf of Mexico in January 1989. The activities of catabolic enzymes were correlated in general with the known metabolic rates of the three species. Activities were much higher in C. sapidus than in Chaceon fenneri and C. quinquedens . In some cases, C. quinquedens had higher activities than C. fenneri . The activities of enzymes of amino acid metabolism (glutamate dehydrogenase and alanine aminotransferase) were higher in C. quinquedens , which had high hemolymph (ammonia) and ammonia excretion rates. The activity of lactate dehydrogenase (LDH) fo C. fenneri and C. quinquedens were correlated with the two species' abilities to withstand hypoxia. The more hypoxia-tolerant species, C. quinquedens , had higher activity of LDH in its muscles than did C. fenneri .

TI: Title
Exploration for golden crab, Geryon fenneri , in the South Atlantic Bight: Distribution, population structure, and gear assessment.
AU: Author
Wenner, EL; Ulrich, GF; Wise, JB
AF: Author Affiliation
Mar. Resour. Res. Inst., South Carolina Wildl. and Mar. Resour. Dep., P.O. Box 12559, Charleston, SC 29412, USA
SO: Source
Fishery Bulletin [FISH. BULL.], vol. 85, no. 3, pp. 547-560, 1987
IS: ISSN

0090-0656

AB: Abstract

Exploratory trapping for golden crab, Geryon fenneri , was conducted from 5 August 1985 to 21 February 1986 off South Carolina and Georgia. A buoyed system with strings of six traps (three side-entry Fathoms Plus and three top-entry Florida traps) was fished in six depth strata: 274-366 m, 367-457 m, 458-549 m, 550-640 m, 641-732 m, and 733-823 m. Catches of golden crab were highly variable between strata. Catch per trap increased from 1.6 crabs (1.67 kg) in the shallowest stratum sampled to a maximum abundance of 22.3 crabs/trap (18.04 kg/trap) in the 458-549 m depth zone. Catches abruptly declined in the deeper strata sampled. Number of golden crab per trap (1.7:1) and weight per trap (1.6:1) in the Florida trap exceeded that in the Fathoms Plus trap for all completed sets.

TI: Title

In situ estimates of density of golden crab, Chaceon fenneri , from habitats on the continental slope, southeastern U.S.

AU: Author

Wenner, EL; Barans, CA

AF: Author Affiliation

Mar. Resour. Res. Inst., Box 12559, Charleston, SC 29412, USA

SO: Source

Bulletin of Marine Science [BULL. MAR. SCI.], vol. 46, no. 3, pp. 723-734, 1990

IS: ISSN

0007-4977

AB: Abstract

Observations on density and habitat of golden crab, Chaceon fenneri , were made from a submersible along 85 transects in depths of 389-567 m 122 km southeast of Charleston, South Carolina. Additional observations on habitat were made on 16 transects that crossed isobaths between 293-517 m. Seven habitat types were identified during dives: a flat foraminiferon ooze habitat (405-567 m); coral mounds (503-555 m); ripple habitat (320-359 m); dunes (389-472 m); black pebble habitat (446-564 m); low outcrop (466-512 m); and soft-bioturbated habitat (293-475 m). A total of 109 C. fenneri were sighted within the 583,480 m super(2) of bottom surveyed. Density (mean no. multiplied by 1,000/m super(2)) was significantly different among habitats, with highest values (0,7 multiplied by 1,000/m super(2)) noted among low rock outcrops. Lowest densities were observed in the dune habitat (<0.1 multiplied by 1,000/m super(2)), while densities for other habitats were similar (0.15-0.22 multiplied by 1,000/m super(2)).

Appendix B. List of Contributions to SAFE as Provided by NMFS SERO

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive N.
St. Petersburg, FL 33702
(727) 570-5335; FAX (727) 570-5300

March 24, 1999 F/SERX1:RCR:dcp

Mr. Robert Mahood, Executive Director
South Atlantic Fishery Management Council
1 Southpark Circle, Suite 306
Charlotte, SC 29407

Dear Bob,

Enclosed are lists of contributions to the SAFE reports for the FMPs under your Council's jurisdiction. The lists represents contributions sent directly to our office as of Friday, March 19, 1999, and also includes some items extracted from Council briefing books and other sources.

Dr. Kemmerer recently announced that the responsibility for SAFE reporting is being transferred from the Fisheries Economics Office to the Sustainable Fisheries Division (Dr. James Weaver). The March 19, 1999 cut-off date for this report has been established to avoid confusion during the transition period. The Fisheries Economics Office will temporarily maintain a file of new contributions received after March 19, 1999. These documents will be given to the Sustainable Fisheries Division at the time the transition is completed and they become responsible for maintaining the SAFE files.

Sincerely yours,

Richard C. Raulerson, Chief
Fisheries Economics Office

Attachment: Lists of SAFE Contributions

RECEIVED
MAR 2 9 1999

cc: F/SE - Andrew Kemmerer/Carol Ballew
F/SER2 - James Weaver/Mike Justen
F/SF - George Darcy/Richard Surdi
SEFSC - Brad Brown/Alex Chester
F/SEC7 - John Merriner
F/SEC5 - Tom McIlwayne

1

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Stock Assessment and Fisheries Evaluation Report Contributions
South Atlantic Fishery Management Council
Golden Crab

Summary Update of the Golden Crab Trip Report Logbook, Trip Interview Data and Preliminary Production Model Analysis, PRD-97/98-31	Douglas E. Harper and Gerald P. Scott	June 18, 1998
Golden Crab Fishery Development, SERO-ECON-98-15	William O. Antozzi	June 12, 1998
Golden Crab Landings and Exvessel Prices, SERO-ECON-98-17	John Vondruska	June 12, 1998
Golden Crab Progress Report, SERO-ECON-98-01	William O. Antozzi	October 1, 1997

Appendix C. Fishery Status Report Through 1998

NMFS HAS NOT PROVIDED THE REPORT AS OF THIS DATE

Appendix D. Annual Report Tracking Permit Transactions

Ed Burgess,5/21/99 9:10 AM -0500,Golden Crab data 1

Conversion: Allowed
Priority: normal
Disclose-Recipients: Prohibited
Alternate-Recipient: Allowed
Date: 21 May 1999 10:10:00 -0400
From: Ed Burgess <Ed.Burgess@noaa.gov>
To: Gregg Waugh <Gregg.Waugh@noaa.gov>,
Mike Justen <Mike.Justen@noaa.gov>
cc: James Weaver <James.Weaver@noaa.gov>,
Ed Burgess <Ed.Burgess@noaa.gov>,
Raymond Slagle <Raymond.Slagle@noaa.gov>,
Lorie Monn <Lorie.Monn@noaa.gov>,
Susan Jarvis <Susan.Jarvis@noaa.gov>,
Cheryl Franzen <Cheryl.Franzen@noaa.gov>,
"Janet L. Miller" <Janet.L.Miller@noaa.gov>,
Joann Turner <Joann.Turner@noaa.gov>
Subject: Golden Crab data

Following is the golden crab info for the Safe Report. If you need additional info let me know.

Ed

Golden Crab Statistics 5/20/1999

Initial 1996 issuance by zone

Northern	2
Middle	6
Southern	27

Auto renewal 1997 by zone

Northern	1
Middle	4
Southern	23

Not renewed 1997 due to reporting noncompliance

Northern	1
Middle	2
Southern	4

Vessels meeting the catch requirement to renew 1998

Northern	0
Middle	3
Southern	10

Vessels renewed 1998 by zone

Northern	0
Middle	3
Southern	7

Number of transfers

1997	2
1998	2
1999	0

Raymond Slagle,5/27/99 10:49 AM -0500,Golden Crab data 1

Conversion: Allowed
Priority: normal
Disclose-Recipients: Prohibited
Alternate-Recipient: Allowed
Date: 27 May 1999 11:49:32 -0400
From: Raymond Slagle <Raymond.Slagle@noaa.gov>
To: Gregg_Waugh@safmc.nmfs.gov
cc: Ed Burgess <Ed.Burgess@noaa.gov>
Subject: Golden Crab data
MIME-Version: 1.0

Gregg

The attached file contains the names and addresses of the currently permitted vessels in the golden crab fishery.

There are three vessels in the southern zone that have not renewed their golden crab permit. There is nothing in the regulations prohibiting the renewal of these three permits.

Content-Type: application/octet-stream; name="goldcrab.txt"
Content-Disposition: attachment; filename="goldcrab.txt"
Content-Description: goldcrab.txt
FTBP-Modification-Date: 27 May 1999 15:49:00 Z
FTBP-Object-Size: 3395

goldcrab.txt

Appendix E. Economic Assessment Report

NMFS HAS NOT PROVIDED THE REPORT AS OF THIS DATE

Appendix F. Summary Update of the Golden Crab Trip Report, Logbook, Trip Interview Data and Preliminary Prodcution Model Analysis (NMFS SEFSC-PRD-97/98-31)

SUMMARY UPDATE OF THE GOLDEN CRAB TRIP REPORT LOGBOOK TRIP INTERVIEW DATA AND PRELIMINARY PRODUCTION MODEL ANALYSIS

Report to the South Atlantic Fishery Management Council
Golden Crab Advisory Committee

St. Augustine, Florida
June 18, 1998

Prepared by Douglas E. Harper and Gerald P. Scott
National Marine Fisheries Service
Southeast Fisheries Science Center
Miami, Florida

Contribution Number PRD-97/98-31

BACKGROUND

In November 1995, a voluntary logbook program for the golden crab fishery in Atlantic Ocean waters off the southeastern U.S. was initiated by the National Marine Fisheries Service (NMFS). This Golden Crab Trip Report Logbook program became mandatory when regulations for the golden crab fishery management plan went into effect on October 28, 1996. Regulations require that all fishers that have been issued a Federal vessel permit for the golden crab fishery in the South Atlantic region must complete and submit a logbook form for each fishing trip on which golden crabs are caught. All reporting must be done on log forms that are provided by the Southeast Fisheries Science Center (SEFSC) and must be returned to the SEFSC for data processing.

Fishing activity for a single trip is reported on one log form (see Appendix A). The form is designed so that fishers can report the catch, number of traps, fishing location, depth and soak time for each line or string of traps that are hauled during the trip.

For regulatory purposes, the South Atlantic region is divided into 3 golden crab fishing zones. The Northern Zone is defined as the EEZ north of 28 degrees N, latitude. The Middle Zone is defined as the EEZ from 25 degrees N, latitude to 28 degrees N, latitude. The Southern Zone is defined as the EEZ south of 25 degrees N, latitude. Federal vessel permits are issued for a specific zone and fishing is only allowed in the zone for which the permit is issued.

The purpose of the logbook program was to provide a suitable method of comprehensive data collection for the fishery. Additional golden crab fishery data is available in the Trip Interview Program (TIP). TIP data collection is conducted by NMFS and state fishery agents who sample catches at the conclusion of commercial fishing trips and provides information on size frequency of individual crabs landed. This report summarizes logbook program and TIP sampling information that has been collected to date. In addition, a preliminary stock assessment production model analysis is presented.

Results and Discussion

The vessel permit and logbook reporting requirements took effect on October 28, 1996. As a result of the vessel permit requirements, 35 vessels were issued permits to catch, possess and sell golden crab in the South Atlantic region. The breakdown of vessel permits by golden crab fishing zone is as follows: Southern Zone - 27 permits; Middle Zone - 6 permits; and Northern Zone - 2 permits. In compliance with the reporting requirements, 31 of the 35 permitted vessels have submitted logbook forms to the Southeast Fisheries Science Center. Four of the permitted vessels have not submitted any logbook forms.

The reporting regulations require that a logbook must be submitted for every trip where golden crabs are caught (possessed). If a permitted vessel did not fish during a calendar month, a report has to be submitted stating that the vessel was inactive during with regard to golden crab fishing during the month. Of the 35 permitted vessels, 11 vessels fished for golden crabs and submitted 434 logbook reports with their catch and effort data for each trip as of May 15, 1998.

Because no-fishing reports are required for a calendar month, the distribution of logbook submissions can be reviewed monthly. For the 12 month period from November 1996 through October 1997, 23 permit holders submitted reports for every month. For November 1997, through March 1998, 18 permit holders submitted a report for each month.

Reported Logbook Golden Crab Catches

Table 1 provides a monthly summary of the information for the 434 Golden Crab Trip Report Logbook forms which reported fishing activity. For the Middle Zone (area between 25° N, latitude and 28°

N, latitude), estimated monthly golden crab catches from 330 trips completed during the entire period, November 1995 through April 1998, were 1.39 million pounds. Over the entire time period Middle Zone monthly catches averaged 46,315 pounds and ranged from 13,600 pounds for November 1995 to 84,872 pounds for May 1997 (Figure 1). Logbook report forms representing 104 trips with golden crab landings made in the Southern Zone (area south of 25°) between February 1997 and March 1998 were submitted. Southern Zone estimated golden crab catches for these reported trips were 395,275 and averaged 28,234 pounds per month over the fourteen reported months.

Catch-per-unit-effort

The number of trap hauls reported for the 434 trips in the golden crab logbook database was 49,301 (Table 1, Figure 2). During the logbook time period the average number of traps hauled per month was 1,216 in the Middle Zone and 860 in the Southern Zone. Harper (1996) reported that golden crab catch-per-unit-effort as measured by mean catch (pounds) per trap haul was increasing during the period November 1995 through March 1996. With additional trips over a longer time period available for calculations, CPUE trends appear to be exhibiting seasonal patterns with peak CPUE occurring in winter-spring (December through May) with lower CPUE values calculated during summer-fall (June through November). For the Middle Zone, golden crab monthly mean catch per trap haul was 42.8 pounds during winter-spring and 32.7 pounds during summer-fall (Figure 3).

Incidental catch

Incidental catch information was estimated by fishers and reported on the Golden Crab Trip Logbook forms. The most frequently reported incidental catch species was the giant isopod, *Bathynomus giganteus*. A total of 17,455 estimated pounds of giant isopod were caught between November 1995 and April 1998 (Table 2). The overall mean catch per trap haul was 0.36 pounds and ranged from 0.12 pounds during May 1996 to 0.61 pounds during October 1996. In general, reported incidental catch of other species was very low. In addition to the giant isopod, nine other species categories representing a total incidental catch of 26.5 pounds over the period November 1995 through April 1998 were reported on the logbook forms. These species categories and estimated catch were: rockfish - 7.5 pounds, hake - 6.0 pounds, whiting - 3.0 pounds, jonah crab - 2.8 pounds, shrimp - 2.0 pounds, queen snapper - 2.0 pounds, squid - 1.2 pounds, red crab - 1.0 pounds, and scorpion fish - 1.0 pounds.

TIP Sampling

TIP sampling of the golden crab fishery began during May 1995. A total of 51 trips have been sampled and 4,801 golden crabs have been measured through December 1997. Table 3 presents the monthly number of crabs measured and carapace width statistics. The overall mean carapace width of sampled golden crabs was 148.5 mm. (N=4,801, std.=12.6) and ranged from 142.5 mm. (N=475,std.=16.3) during September 1995; to 157.7 mm. (N=161,std.=8.3) during January 1997.

Preliminary Production Model Analysis

Catch and estimated effort data for the period 1986-present were fit with a non-equilibrium production model (Prager 1993) to estimate stock status relative to MSY levels. Golden crab quarterly catch in pounds for the South Atlantic region were obtained from the Accumulated Landings System for the period 1986 through October 1996. After October 1996, golden crab catch was derived from the Golden Crab Trip Report Logbook. Quarterly effort levels were estimated by dividing quarterly catch by observed CPUE (lbs per trap haul). CPUE data for 1986 were available in Erdman (1990). CPUE for the most recent period (1996-1998) were from the Golden Crab logbook reports described earlier. The production model was fit to both quarterly and annual data. However, only 3 paired annual observations of catch and effort were available, making the annual model fit of questionable value. Results of the annual and quarterly model fits depended on assumptions made about the initial biomass level. Quarterly catch and estimated effort data are provided in Table 4. For this preliminary analysis, the fishing year was defined to begin in February; thus, the first quarter of the fishing year ended in April and the last quarter ended in January. For this analysis, a total of 49 quarters of catch (February 1986 - April 1998) and 14 quarters of effort were available.

The data were first fit assuming that stock biomass was at model carrying capacity ($K=2B_{MSY}$) in January 1986. A total of 501 bootstrap fits of the model to the 14 paired catch and effort observations (Table 4) were used to estimate uncertainty in the model parameters of interest. As the model was fit to quarterly data, estimates of annual parameters, such as MSY, can be obtained by multiplying the parameters of concern by 4. From this model, current biomass is estimated to be at about that level which could produce MSY and the median estimate of annual MSY is on the order of 847,000 lbs per year (approximate 80% CI, ~650,000 - 920,000 lbs per year). The results of this fit are shown in Table 5. Recent (quarterly) fishing mortality rates were estimated to range from about 0.5 to 2 times that needed to achieve quarterly MSY. The estimated time-trajectory of relative (quarterly) biomass and relative (quarterly) fishing mortality rate are shown in Figure 5.

An alternative model was fit to the data in which initial biomass was not fixed at K, but estimated. As above, a total of 501 bootstrap fits of this model to the 14 paired catch and effort observations (Table 4) were used to characterize the uncertainty in parameter estimates. From this model, initial biomass (January 1986) was estimated to be more than twice carrying capacity, current biomass was estimated to be about 50% above that level which could produce MSY and recent fishing mortality rates ranged from about 0.25 to about $1.0F_{MSY}$ From this model, the estimate of annual MSY is less precisely estimated although the median estimate is on the order of 1,070,000 lbs per year (approximate 80% CI, ~707,000 - >60,000,000 lbs per year). The results of this fit are shown in Table 6. The estimated time-trajectory of relative (quarterly) biomass and relative (quarterly) fishing mortality rate are shown in Figure 6.

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Erdman, R.B. 1990. Reproductive ecology and distribution of deep sea crabs (Family Geryonidae) from the southeast Florida and the eastern Gulf of Mexico. PhD Dissertation, Department of Marine Science, University of south Florida, 147pp.

Harper, D.E. 1996. Summary report on golden crab trends in landings and CPUE, 1986-1995 from the waters off the southeast U.S. coast. National Marine Fisheries Service, Southeast Fisheries Science Center, MIA-95/96-42 8pp.

Prager, M.H. 1993. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin. 92:374-389.

Table 1 - Monthly summary of information reported in the South Atlantic Golden Crab Trip Report Logbook Program (November 1985 through April 1998).

MIDDLE ZONE

Year	Month	Catch Weight (lbs)	Traps Hauled	Strings Hauled	Number Trips	Depth fished average (feet)	Soak Time average (days)
1995	November	13,600	399	12	4	1,083.3	8.6
	December	48,060	1,202	34	12	1,093.8	7.6
1996	January	38,650	721	21	9	1,100.0	8.0
	February	32,300	542	16	9	1,100.0	8.2
	March	43,050	807	25	11	1,100.0	7.6
	April	47,950	1,128	32	11	1,096.9	17.8
	May	53,140	1,426	41	14	1,110.4	10.3
	June	48,150	1,821	50	12	1,130.8	7.4
	July	41,705	1,363	39	11	1,161.7	7.3
	August	46,950	1,525	41	12	1,183.9	11.1
	September	49,000	1,595	44	13	1,202.3	6.5
	October	32,635	1,079	33	10	1,222.9	17.9
	November	26,800	960	27	9	1,214.6	9.3
	December	62,830	1,608	44	13	1,189.4	8.0
1997	January	72,020	1,580	45	13	1,177.6	9.2
	February	57,100	1,202	33	10	1,158.3	10.5
	March	58,920	1,288	34	12	1,088.9	6.9
	April	62,900	1,417	37	12	1,104.0	10.5
	May	84,872	2,003	53	17	1,201.0	8.5
	June	43,580	1,096	30	10	1,102.7	7.9
	July	60,648	1,652	48	18	1,145.4	10.4
	August	63,035	1,792	47	15	1,191.0	8.5
	September	55,330	1,484	39	12	1,190.8	8.6
	October	49,041	1,439	38	13	1,189.2	12.1
	November	24,500	766	21	6	1,203.0	11.0
	December	29,950	874	26	9	1,199.4	7.7
1998	January	36,130	937	27	8	1,193.8	10.7
	February	45,070	1,182	32	10	1,184.2	8.0
	March	43,630	1,124	29	10	1,209.1	12.6
	April	17,900	455	13	5	1,176.9	8.0
	Total	1,389,446	36,467	1,011	330	1,160.4	9.5

SOUTHERN ZONE

Year	Month	Catch Weight (lbs)	Traps Hauled	Strings Hauled	Number Trips	Depth fished average (feet)	Soak Time average (days)
1997	February	6,712	155	3	2	1,200.0	3.0
	March	15,666	610	12	4	1,217.0	4.8
	April	24,980	900	18	10	1,358.3	8.5
	May	108,388	3,427	77	28	1,762.3	7.3
	June	54,773	1,442	32	14	1,892.2	11.7
	July	52,990	1,195	25	9	1,940.0	11.8
	August	15,760	367	9	4	1,738.9	11.6
	September	21,240	808	15	7	2,001.3	17.1
	October	15,927	450	9	3	1,933.3	20.0
	November	17,667	651	14	5	1,705.7	24.8
	December	9,595	250	6	3	1,733.3	22.2
1998	January	18,480	624	16	4	1,008.5	26.4
	February	28,697	904	25	9	1,134.4	18.0
	March	4,400	251	7	2	1,787.1	15.4
	April						
	Total	395,275	12,034	268	104	1,761.4	12.9

Table 2.- Estimated incidental giant isopod catches reported in the Golden Crab Trip Report Logbook, November 1995 through April 1998.

Year	Month	Catch POUNDS	Catch per trap haul POUNDS
1995	November	206	0.52
	December	405	0.34
1996	January	190	0.26
	February	105	0.19
	March	291	0.36
	April	188	0.17
	May	171	0.12
	June	607	0.33
	July	646	0.47
	August	499	0.33
	September	813	0.51
	October	659	0.61
	November	476	0.27
	December	607	0.38
1997	January	530	0.34
	February	447	0.33
	March	612	0.32
	April	941	0.41
	May	2,269	0.42
	June	955	0.38
	July	691	0.24
	August	641	0.30
	September	831	0.36
	October	780	0.41
	November	540	0.38
	December	615	0.55
1998	January	547	0.35
	February	539	0.26
	March	436	0.32
	April	218	0.48
Total		**17,455**	**0.35**

Table 3. - Monthy summary of Trip Interview Program sampling for the golden crab fishery. Individual golden crabs from commercial landings are measured to the nearest mm. carapace width (CW) by NMFS and state port agents.

Year	Month	Number Measured	Mean CW (mm)	Standard Deviation	Minimum CW (mm)	Maximum CW (mm)
1995	May	74	150.5	10.7	122	177
	June	353	146.8	11.1	119	175
	July	211	147.8	13.0	102	180
	August	37	154.7	20.3	110	181
	September	475	142.5	16.3	108	189
	October	108	154.8	15.2	111	186
	November	202	155.0	14.6	105	188
	December	0				
1996	January	0				
	February	229	146.3	9.7	116	169
	March	25	151.0	11.2	128	180
	April	763	143.5	10.2	112	174
	May	357	144.2	11.2	104	170
	June	208	142.7	11.1	111	170
	July	170	150.4	11.3	125	171
	August	0				
	September	275	154.3	9.0	125	179
	October	138	156.1	11.1	124	180
	November	0				
	December	0				
1997	January	161	157.7	8.3	135	180
	February	0				
	March	293	155.2	9.8	123	182
	April	99	146.4	10.1	112	172
	May	242	151.9	9.2	122	174
	June	223	151.4	10.0	123	183
	July	0				
	August	46	152.7	8.3	130	170
	September	0				
	October	0				
	November	112	151.7	9.4	130	174
	December	0				
Total		**4,801**	**148.5**	**12.6**	**102**	**189**

Table 4. Quarterly catch (lbs) and effort (estimated trap hauls) for the period February 1986-April 1998. Effort was estimated by dividing observed quarterly catch rate (Lbs/Trap Haul) into quarterly catch.

Fishing Year	Quarter	Trap Hauls	Lbs Landed
1986	1	2.302E+01	2.029E+03
	2	6.879E+01	6.471E+03
	3	4.952E+01	4.137E+03
	4	2.445E+02	1.292E+04
1987	5	*	1.721E+04
	6	*	2.910E+04
	7	*	6.589E+03
	8	*	1.766E+03
1988	9	*	1.149E+04
	10	*	8.712E+03
	11	*	4.250E+02
	12	*	1.022E+03
1989	13	*	3.126E+03
	14	*	5.900E+03
	15	*	0.000E+00
	16	*	0.000E+00
1990	17	*	0.000E+00
	18	*	0.000E+00
	19	*	1.100E+02
	20	*	0.000E+00
1991	21	*	2.886E+03
	22	*	3.645E+03
	23	*	2.707E+03
	24	*	2.500E+03
1992	25	*	7.300E+02
	26	*	1.930E+02
	27	*	0.000E+00
	28	*	0.000E+00
1993	29	*	2.456E+04
	30	*	1.855E+04
	31	*	2.000E+02
	32	*	2.398E+03
1994	33	*	0.000E+00
	34	*	0.000E+00
	35	*	0.000E+00
	36	*	4.296E+03
1995	37	*	8.815E+04
	38	*	5.456E+05
	39	*	2.070E+05
	40	4.941E+03	1.936E+05
1996	41	3.616E+03	1.703E+05
	42	1.088E+04	3.279E+05
	43	3.897E+03	1.192E+05
	44	4.148E+03	1.616E+05
1997	45	5.572E+03	2.263E+05
	46	1.082E+04	4.053E+05
	47	6.340E+03	2.203E+05
	48	4.102E+03	1.363E+05
1998	49	3.916E+03	1.397E+05

* Asterisk indicates missing value(s)

Table 5. Results of the bootstrapped analysis for the production model fit to quarterly catch and effort data under the assumption that 1986 biomass was at model carrying capacity.

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL
Biratio	2.000E+00	2.000E+00	0.00%	2.000E+00	2.000E+00	2.000E+00	2.000E+00
K	1.007E+06	9.571E+05	-4.98%	6.724E+05	1.907E+06	7.979E+05	1.364E+06
r	8.290E-01	9.006E-01	8.64%	3.299E-01	1.351E+00	5.532E-01	1.092E+00
q(1)	7.164E-05	7.493E-05	4.59%	3.846E-05	1.135E-04	5.239E-05	9.459E-05
MSY	2.118E+05	2.155E+05	1.74%	1.639E+05	2.302E+05	1.939E+05	2.221E+05
B-ratio	1.076E+00	1.100E+00	2.28%	8.684E-01	1.324E+00	9.688E-01	1.215E+00
F-ratio	6.469E-01	6.321E-01	-2.29%	4.926E-01	9.045E-01	5.545E-01	7.495E-01

Parameters: Biratio, Initial biomass expressed relative to Bmsy = K/2. A value of 2.0 implies initial biomass assumed to be at model carying capacity. K, model carrying capacity. R, Model intrinsic rate of increase. Q(1), catchability coefficient for fishery (1). MSY, estimate of quarterly maximum sustainable yield. B-ratio, estimate of end of last quarter biomass, expressed relative to BMSY. F-ratio, estimate of last quarter fishing mortality rate relative to that which could produce MSY

Table 6. Results of the bootstrapped analysis for the production model fit to quarterly catch and effort data when 1986 initial biomass relative to B_{MSY} was estimated at about 2.5 times carrying capacity.

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL
Biratio	4.492E+00	4.889E+00	8.85%	2.832E+00	6.226E+00	3.681E+00	5.291E+00
K	5.538E+06	5.735E+06	3.55%	1.227E+06	4.101E+08	2.311E+06	4.984E+07
r	1.860E-01	1.815E-01	-2.42%	4.563E-02	6.948E-01	1.008E-01	3.609E-01
q(1)	8.596E-06	7.780E-06	-9.49%	8.446E-08	5.098E-05	1.302E-06	2.614E-05
MSY	2.670E+05	2.602E+05	-2.53%	1.769E+05	1.500E+07	2.159E+05	3.476E+06
Bmsy	2.769E+06	2.867E+06	3.55%	6.134E+05	2.050E+08	1.155E+06	2.492E+07
B-ratio	1.511E+00	1.566E+00	3.61%	1.163E+00	2.054E+00	1.276E+00	1.984E+00
F-ratio	3.312E-01	3.443E-01	3.94%	4.672E-03	6.612E-01	2.125E-02	5.210E-01

Parameters: Biratio, Initial biomass expressed relative to Bmsy = K/2. A value of 2.0 implies initial biomass assumed to be at model carying capacity. K, model carrying capacity. R, Model intrinsic rate of increase. Q(1), catchability_coefficient for fishery (1). MSY, estimate of quarterly maximum sustainable yield. B-ratio, estimate of end of last quarter biomass, expressed relative to BMSY. F-ratio, estimate of last quarter fishing mortality rate relative to that which could produce MSY

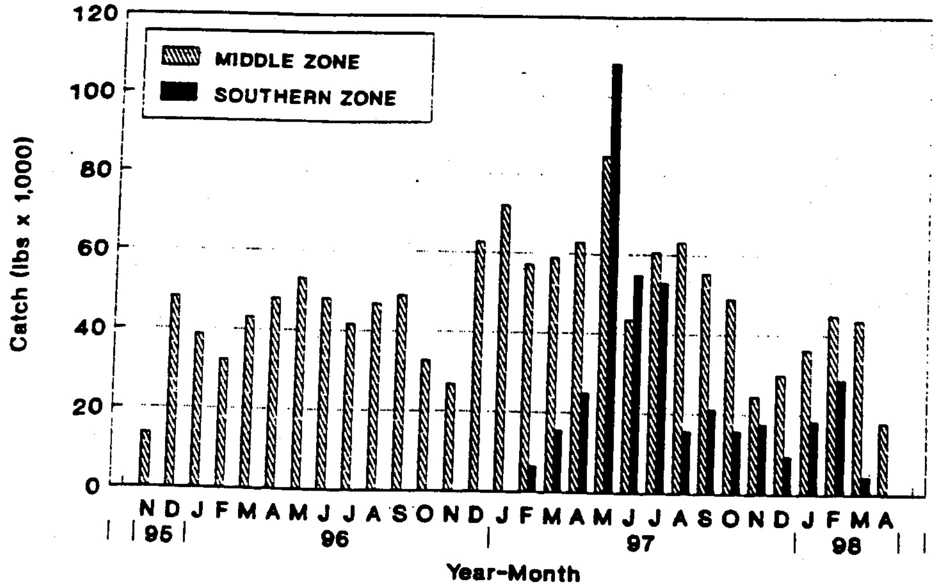

Figure 1. – Reported catch by month and fishing zone from Golden Crab Trip Report Logbook database. A total of 434 logbook trip forms reporting landings were submitted November 1995 through April 1998.

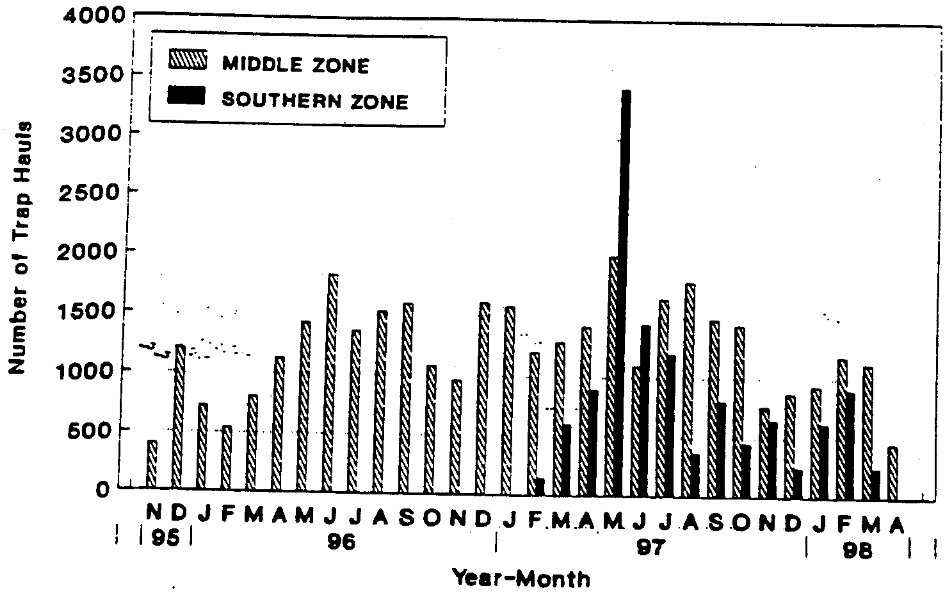

Figure 2. – Reported number of traps hauled by month and fishing zone from the Golden Crab Trip Report Logbook database. A total of 434 logbook trip forms reporting landings were submitted November 1995 through April 1998.

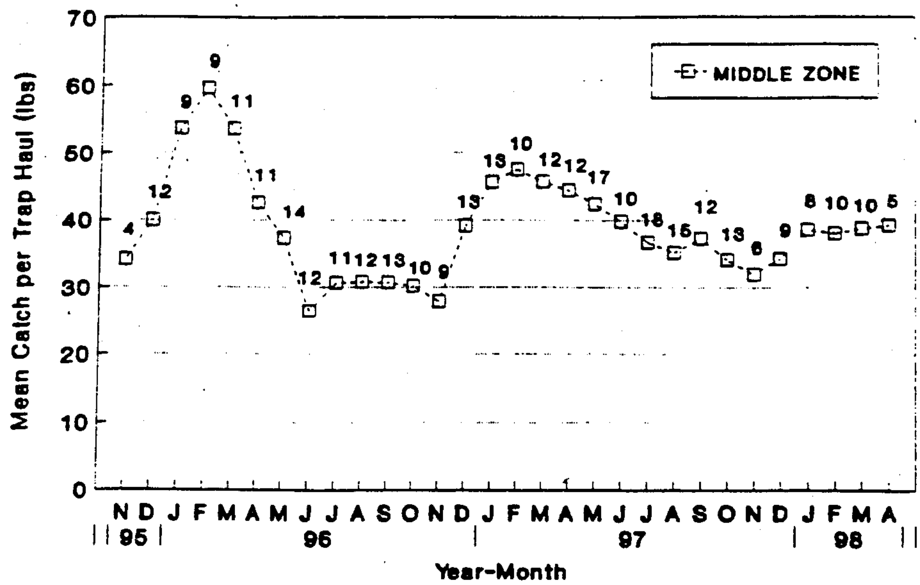

Figure 3. – Monthly CPUE (pounds per trap haul) reported from 330 middle zone trips with landings in the Golden Crab Trip Report Logbook database, November 1995 through April 1998. The number of monthly trips is shown above each monthly CPUE value.

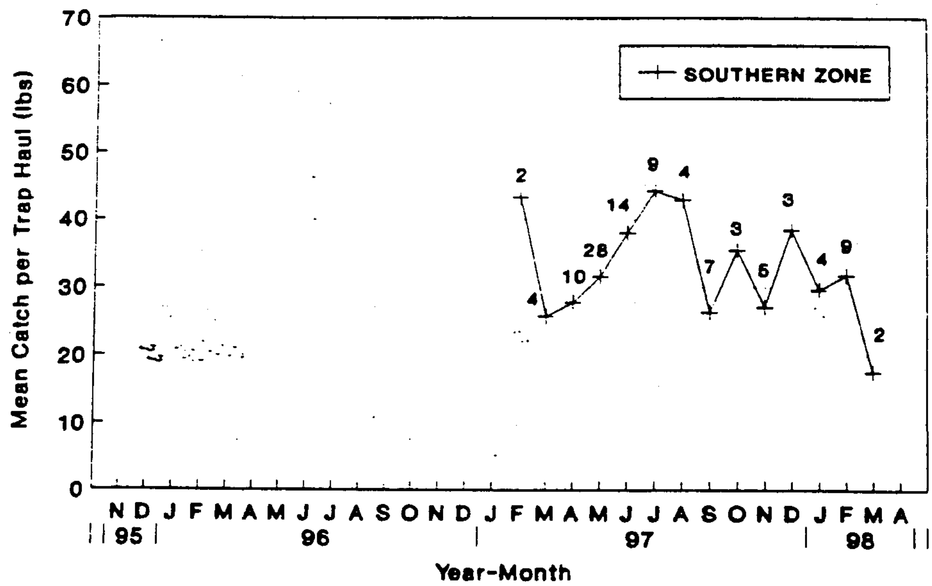

Figure 4. – Monthly CPUE (pounds per trap haul) reported from 104 southern zone trips with landings in the Golden Crab Trip Report Logbook database, February 1997 through March 1998. The number of monthly trips is shown above each monthly CPUE value.

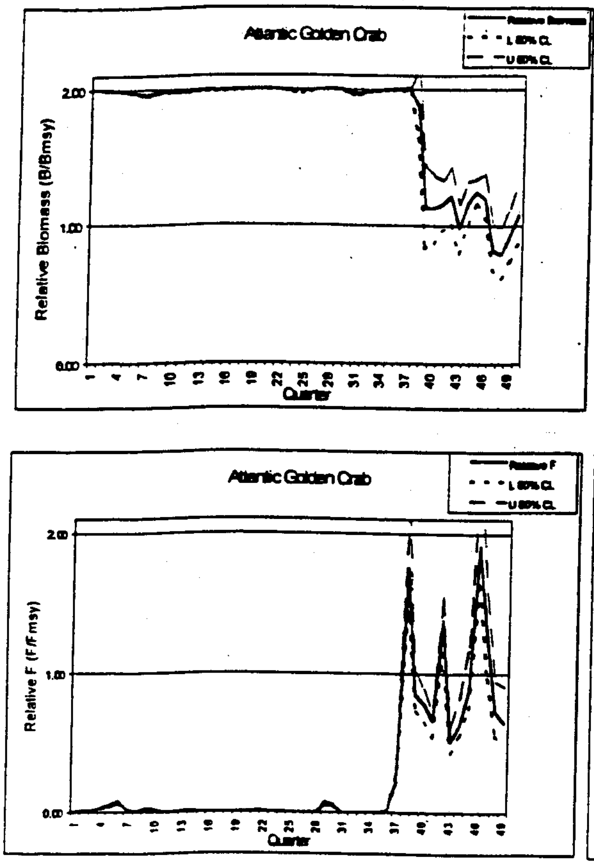

Figure 5. Median estimates of quarterly biomass (upper plate, solid line) and fishing mortality rate (lower plate, solid line) expressed relative to MSY levels for the period 1986-1998, for the model assuming 1986 biomass was at carrying capacity. Dashed lines indicate approximate 80% confidence ranges based on 501 bootstrap trials.

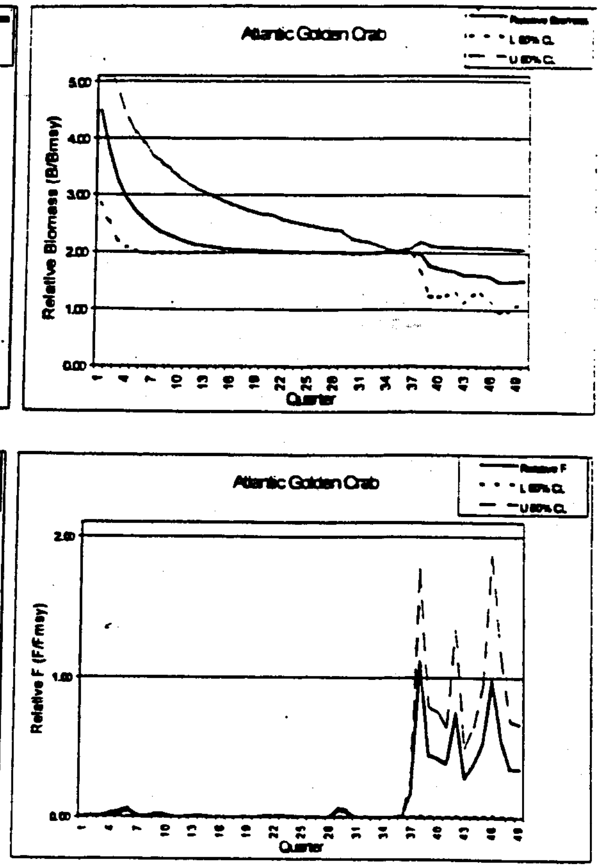

Figure 6. Median estimates of quarterly biomass (upper plate, solid line) and fishing mortality rate (lower plate, solid line) expressed relative to MSY levels for the period 1986-1998, for the model assuming 1986 biomass was more than twice carrying capacity. Dashed lines indicate approximate 80% confidence ranges based on 501 bootstrap trials.

APPENDIX A. – Sample Logbook Form

GOLDEN CRAB TRIP LOGBOOK

OMB# 0648-0016 Exp. 9/30/97

Captain's Signature:	Dealer/Company Name: 1)__________ 2)__________ 3)__________
Vessel Name:	
Vessel ID Number:	
Start Date of Trip _____/_____/19___ (month, day, year)	County Unloaded:
End Date of Trip _____/_____/19___ (month, day, year)	State Unloaded:
No Trips Were Made During _____/19___ (month, year)	Type & Size of Trap Used:

GOLDEN CRAB (Species Code 7102)

String #	Type Trap	mainline C/R	# of Traps	DATE mth/day	Area	Depth	SOAK TIME (hrs)	CATCH WEIGHT estimated lbs
1								
2								
3								
4								
5								

INCIDENTAL CATCH

STRING #	SPECIES write in the name of the species	estimated lbs kept	estimated lbs discarded
#_____			
#_____			
#_____			
#_____			

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Appendix G. Golden Crab Fishery Development (SERO-ECON-98-15)

GOLDEN CRAB FISHERY DEVELOPMENT

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June 10, 1998

SERO-ECON-98-15

Introduction

This report is the fourth in a series that describes the golden crab fishery in the Southeast region. The focus is on how economic forces are affecting the development of this fishery. The previous reports are: "Golden Crab - Market Status," 1995, "Golden Crab Fishery Status," 1996, and "Golden Crab Progress Report," 1997.

Fishing Industry

The golden crab fishery in the Southeast is currently operating at a low level. Reports from National Marine Fisheries Service (NMFS) Port Agents and commercial dealers in Florida indicate that at present (June 1998) there is no production coming from the Gulf of Mexico. The one vessel that had been consistently landing crabs in St. Petersburg has gotten out of the fishery. On the Florida East Coast, landings are steady and light. One vessel owner continues to operate successfully out of Ft. Lauderdale, marketing his catch to mostly local markets.

The expected boost in production which normally occurs in the Florida Keys in the spring and early summer does not appear to be materializing this year (as of early June). Spiny lobster fishermen are reportedly preferring to tie up their boats or to pursue other fisheries. Two vessels are reportedly attempting to overcome gear and mechanical problems before entering the fishery in the lower Keys.

Many of the boats which qualified for permits to fish zones in the S. Atlantic have not had subsequent production. Out of 35 vessels permitted to fish the S. Atlantic, only 11 fished for golden crabs since qualifying (Harper, 1998).

The golden crab fishery is an arduous fishery which requires a substantial investment in vessel and gear and an expert knowledge of fishing grounds and crab behavior. Only those well prepared and determined can pursue this fishery, even when crab prices are attractive.

Monthly golden crab landings appear to show a cyclical pattern (see fig. 1). Greatest production has occurred between March and June (or July). This corresponds to the period when Keys lobster boats normally trap golden crabs. Ex-vessel prices for whole golden crabs do not exhibit any pattern of change over time (see figure 2). Peak dockside price to fishermen occurred in August of 1995, which followed a period of high production. Prices then gradually fell, remaining mostly between 80 and 95 cents thereafter. Presently, the industry is reporting prices mostly at 75 to 80 cents per pound, ex-vessel.

Processing and Marketing

Out of the original five companies processing golden crab in 1995, only one continues (located in Marathon, Florida). Most of the processing has been into golden crab clusters, although there is also the potential to process crabs into picked meat and other value added products.

Although there has been some success in establishing a market niche and name recognition, this success has been limited mostly to the Fort Lauderdale and Miami area.

Golden crab markets are strongly influenced by the wholesale market for snow crab (and to a lesser degree by king and dungeness crab). This is the case because the market form is the same (leg and claw clusters) and the taste and texture are very similar. In fact, the sudden development of the golden crab fishery in early 1995 was primarily due to the scarcity of snow crab at that time (see fig. 3).

Golden crab sells at a discount to snow crab because of market "disadvantages," i.e., failure of the shell to turn red when cooked, like other large crabs, and lack of name recognition nationally, in spite of the fact that the meat is of excellent quality.

Supplies of snow crab are currently plentiful (see fig. 3), resulting in low wholesale prices for snow crab clusters (see fig. 4). This has caused downward pressure on the price structure for golden crabs. To exacerbate the situation, Russian and Canadian snow crab production has also been very high.

The inability to create a significant market niche identity for golden crab, other than as a substitute for snow crab, remains a problem. In order to overcome this dilemma, steady production is necessary, coupled with promotion of golden crab as a high quality, good tasting seafood product.

Golden crab processors could consider the picked meat market form in order to avoid some of the market pressures that the cluster market presents. Golden crab meat is white, flaky, and has a distinctly appealing crab flavor and texture of high quality. Based on studies conducted by Florida Sea Grant, the yield of meat is about 23% (compared with blue crab at 11-14%). This market form would avoid the "failure to turn red" syndrome of the shell-on cluster product form.

Fisheries Management

The Golden Crab Fisheries Management Plan has been in effect since October 1996, when regulations were published to manage the fishery in the S. Atlantic. The regulations include dividing the S. Atlantic into zones, limiting access to certain qualified vessels, requiring vessel and dealer permits and reporting, limiting the size of vessels, prescribing allowable gear, and prohibiting possession of female crabs. Quota management of this fishery was not implemented, however.

The 1997 harvest of golden crabs from the Middle and Southern Zones of the S. Atlantic totaled about 1 million pounds, according to data provided by the S. Atlantic Golden Crab Logbook Program. This approximates the median estimate MSY (maximum sustainable yield) for these two zones (Harper, 1998). Thus, if harvesting continues at this pace, the fishery appears to be about where it should be for these two zones.

Some industry members are concerned about the current lack of production and have expressed opinions that the industry will not be successful without sustained production (as opposed to seasonal production). In order for this to occur, according to these sources, large vessels (> 50 feet) are needed to cope with the frequently rough sea conditions found offshore and to provide the stability for trap deployment and retrieval that a large vessel provides. These sources advocate the liberalization by the S. Atlantic Council of current regulations pertaining to the transfer of a golden crab permit from a smaller vessel to a larger one (currently restricted to a one-time increase of no more than 10% in length). The rationale provided is that many permits will expire this fall because of the failure of some permit holders to produce the required 5,000 pounds to renew. Thus, according to this argument, the total harvesting capacity of the fleet will not be increased even if some permitees are allowed to switch to larger vessels.

Both the Gulf of Mexico (especially the Florida West Coast) and the Northern Zone of the S. Atlantic appear to have potential for increased production. The Gulf apparently has lost its only producing vessel. The owners revealed that they have no current intentions of reengaging in the fishery. The Northern Zone has never had much production except for exploratory fishing.

Outlook

The short term outlook for the golden crab fishery will be highly influenced by the overall market supply of other large crabs, principally snow crab. Indications are that the snow crab market will continue to be depressed through much of 1998. This is due to large amounts of low-priced Alaskan, Canadian, and Russian crabs entering the market (and remaining in frozen inventory) coupled with the fact that one of the major crab markets, Japan, is undergoing a recession, resulting in low demand and prices.

Long term, the outlook changes. According to NMFS biologists in Alaska, the large year class of opilio snow crabs that is now being harvested may be played out by the year 2000. If the history of this fishery is any indication, the harvest quota may then drop by half, and by half again the following year. At this time, the market for large crabs could strengthen, and the golden crab industry could potentially realize a better price structure, from fishermen to processors. This could result in increased fishing, especially in the Gulf of Mexico and the Northern Zone of the South Atlantic.

Summary

In summary, current indications are that the expense of initiating and participating in the golden crab fishery, coupled with plentiful supplies of opilio and other large crabs, are resulting in a golden crab fishery that is operating at a low but stable level.

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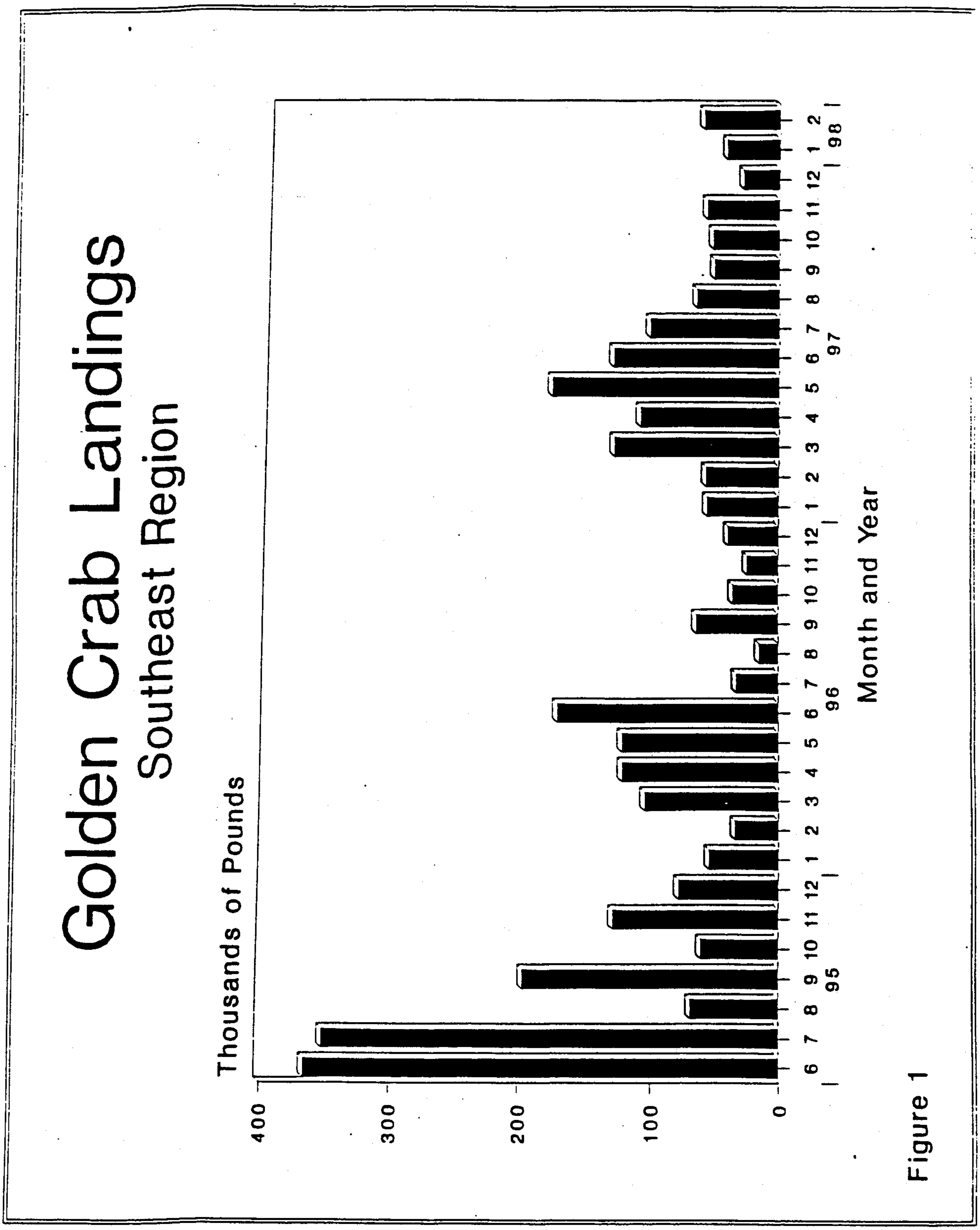

Golden Crab Landings
Southeast Region
Thousands of Pounds
0
100
200
300
400
6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2
95
96
97
98
Month and Year

Figure 1

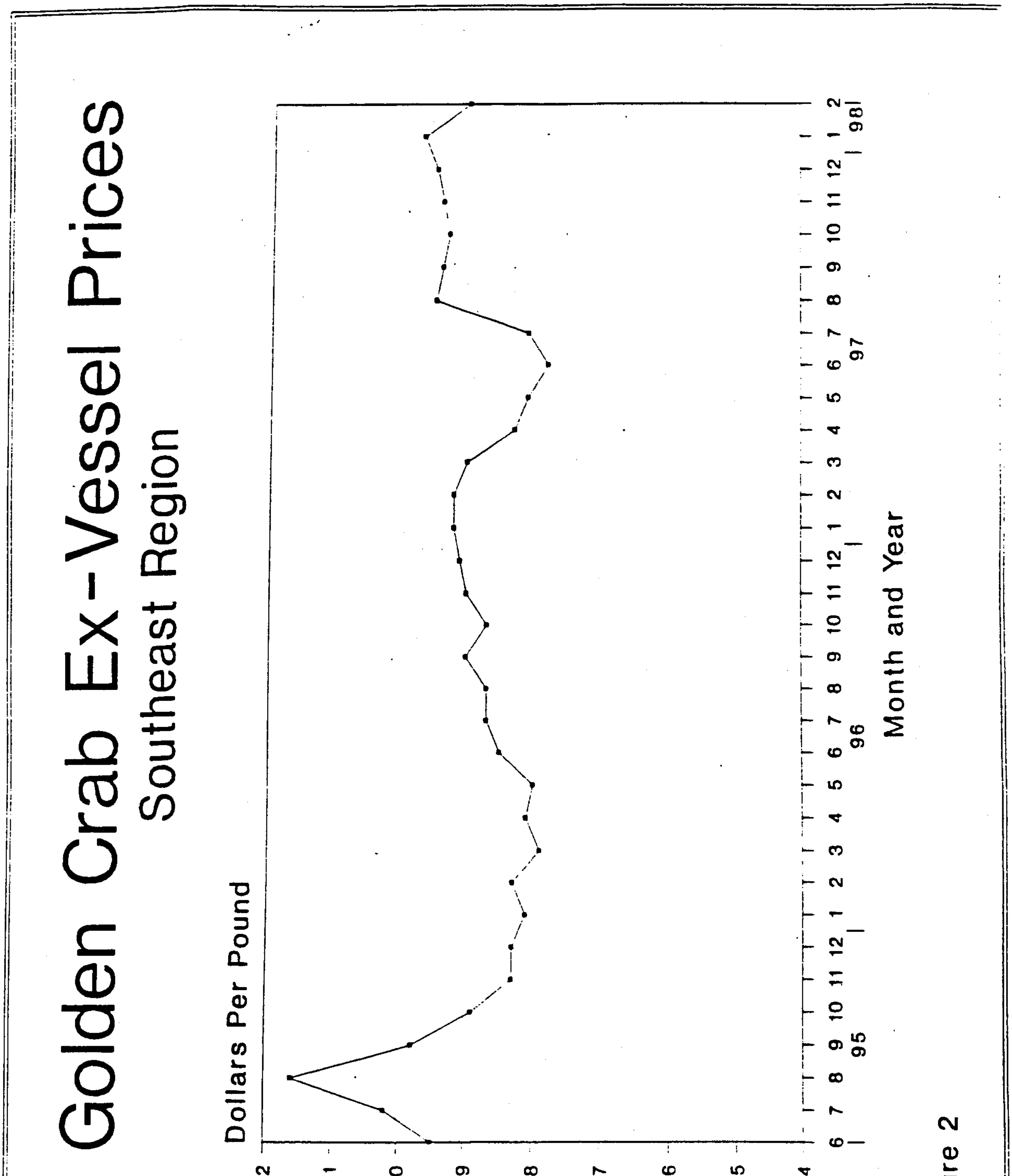
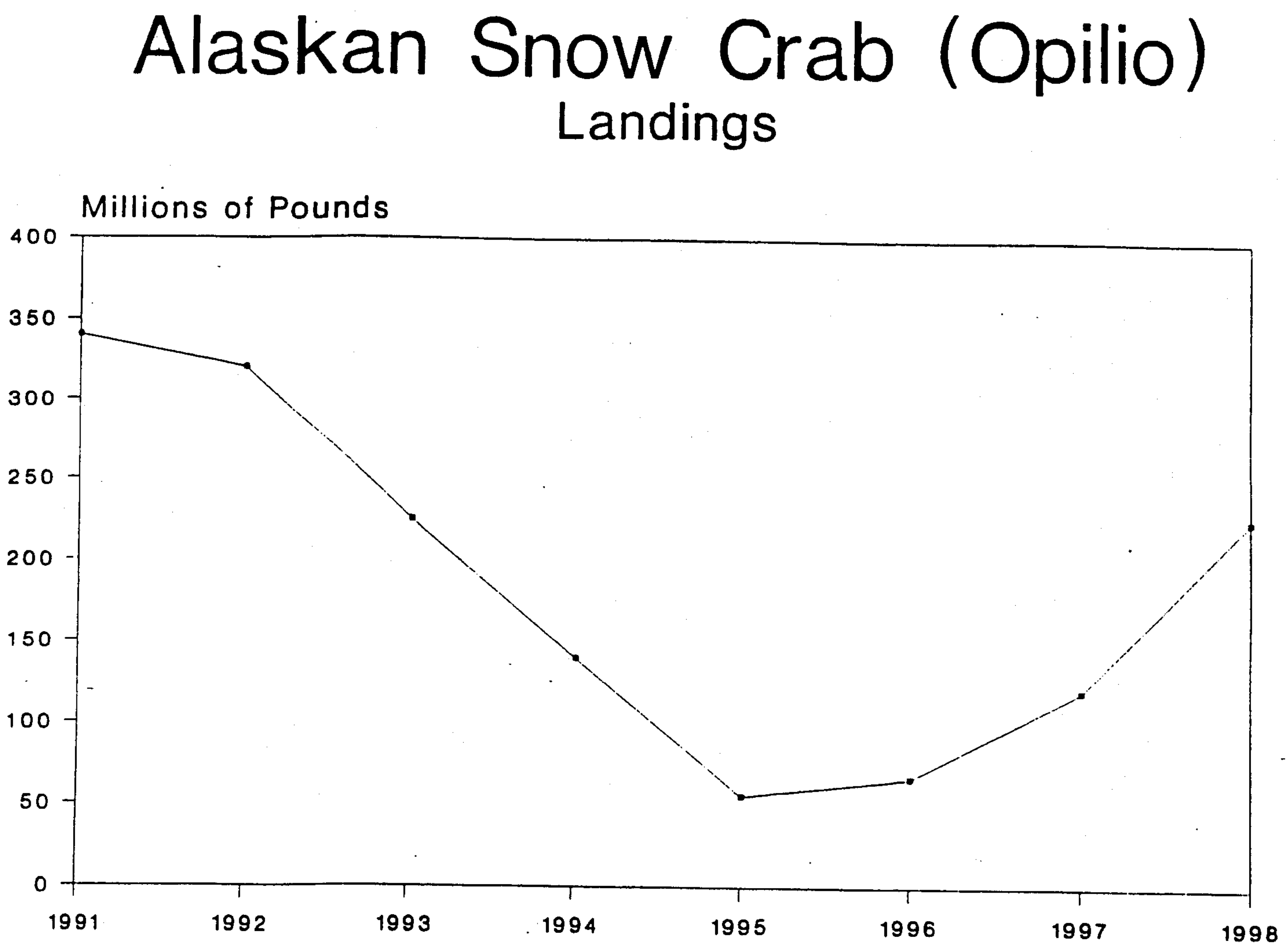
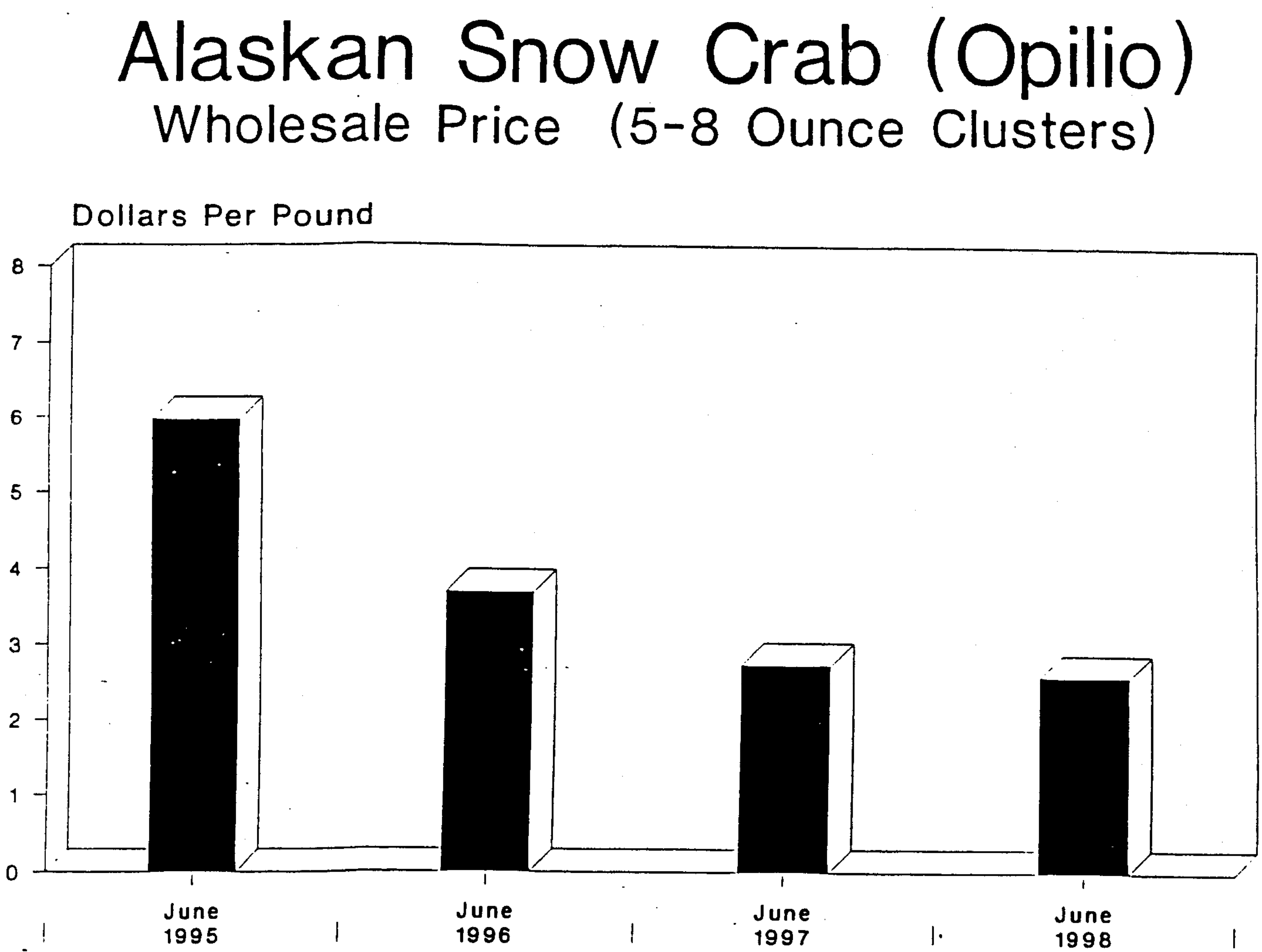

Golden Crab Ex-Vessel Prices
Southeast Region
Dollars Per Pound
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
Month and Year
95
96
97
98

Figure 2


Alaskan Snow Crab (Opilio)
Landings
Millions of Pounds
400
350
300
250
200
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998

igure 3



gure 4 (Price at 1 year Intervals)

Appendix H. Golden Crab Landings and Exvessel Prices (SERO-ECON-98-17)

Golden Crab Landings and Exvessel Prices

Prepared by:

John Vondruska
National Marine Fisheries Service
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June 12, 1998

SERO-ECON-98-17

Golden Crab Landings and Exvessel Prices

A preliminary assessment of monthly data for January 1995 to February 1998 on the harvest of golden crab was done to suggest the nature of possible statistical relationships among variables, especially between monthly landings and exvessel prices (Table 1 and Figures 1-3). When used in a model along with other variables, landings and exvessel prices are important variables that may be used to represent consumer (buyer) and producer (seller) behavior in separate equations. On the consumer side (demand equation), one would expect an increase in landings to reduce price, disregarding the influence of income, prices or suplies of substitute products and other factors that may affect consumers; i.e., in a carefully specified demand equation, there would be an expected negative relationship between the quantity landed and exvessel price based on economic theory. On the producer side (supply equation), one would expect an increase in landings to result from an increase in price, disregarding other factors that may affect producers; i.e., in a carefully specified supply equation, there would be an an expected positive relationship between landings and exvessel price.

Results

The statistical properties ("regression output" from Lotus 123 software) for the three two-variable equations for the golden crab fishery in Table 1 should be taken as indications of the need for further data and work, not as indications of the nature of the behavior of either consumers or producers of golden crab. In the equation, price = f (landings), the low value for R-squared indicates that variation in landings explains very little of the variation in price. Values for R-squared are expected to be positive and in the 0 to 1 range. Figure 3 is a scatter diagram of paired exvessel prices and landings. In the equation traps = f (price), price appears to have little effect on the number of traps deployed (Table 1). On the other hand, in the equation landings = f (traps), the higher R-Squared value suggests that the number of traps has a positive effect on landings, as might be expected.

Background

Antozzi (1997 and 1998) reports that there was a resurgence of fishing for golden crab in the southeastern United States starting in 1995 based in part on strong market demand and high prices resulting from production shortfalls for the smaller of two snow (tanner) crabs (*Chionoecetes c. opilio*). Most notably, substantial landings of the *c. opilio* snow crab may occur in the United States (Alaska), Canada (east coast) and the former Soviet Union (east coast). The effect on the golden crab fishery of variations in landings of snow crab in its major harvesting areas depends in part on the diversity of products. There appears to be greater diversity for the Canadian snow crab fishery (FAO, 1995, pp. 21-22). Including both species of snow crab (*c. opilio* and *c. bairdi*), U.S. landings of snow crab fell from about 357 million pounds in 1991 to 68 million pounds by 1996 (NMFS, 1997, p. 118). According to preliminary data, landings of the smaller, opilio snow crab in Alaska fell from 328 million pounds in 1991 to 66 million pounds by 1996 and then increased to 117 million pounds by 1997 (Pacific Fishing, March 1998, pp. 88-89). There is a management imposed guideline for 1998 of 234 million pounds, and the exvessel price for opilio snow crab in Alaska fell from $1.17 per pound in 1996 to $0.75 in 1997 and then to $0.54 in early 1998 (Ibid.).

To the extent that golden crab appears to have found its own market niche in the United States (Antozzi, 1997 and 1998), demand, sales and prices may be less influenced by what happens to snow crab production and prices. Still, the increased production and lower prices of the smaller snow crab, *c. opilio*, in 1997-98 could have an effect on the demand and prices for golden crab. Note that the latest available NMFS data on the exvessel price for golden crab (to February 1998) would not reveal the full effect of the increased production and lower prices for snow crab, *c. opilio* (Table 1 and Figure 1). That is, based on seasonal indicators for a short time series (January 1995 to February 1998), it appears that prices of golden crab could be expected to decline during the early months of a calendar year (when snow crab landings are high) and then increase later (when snow crab landings are low) (Figure 2).

Fishing for golden crab is a costly activity (Antozzi, 1997 and 1998). On an annual basis, landings went from 1.73 million pounds in 1995 (average price, $0.96 a pound) to 0.83 million pounds in 1996 (average price, $0.84) and to 1.03 million pounds in 1997 (average price, $0.87). It appears that monthly prices in the range of about $0.80 to $1.00 a pound have been sufficient to keep landings at about a million pounds per year in 1996 and 1997 or about 20,000 to 180,000 pounds per month (Figure 1). Prices and/or landings during four months of 1995 were higher (Table 1, Figure 1). Monthly landings and prices are quite variable, and trends are difficult to discern visually (Figure 1). If one tries to envision a straight line to represent the volatile data over time in Figure 1, it appears that there may have been something of an upward trend in prices from late 1995 and early 1996 (say 80 cents per pound) to early 1998 (say 90 cents a pound). It is more difficult to envision trends in the monthly landings.

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Table 1.--Southeast golden crab landings, value & exvessel price, and effort

Month	Southeast landings (NC-TX) Thousand pounds	Price, $/pound	Value, dollars	Logbook data for South Atlantic Council zones: Middle zone traps hauled	Middle zone thousand pounds	Southern zone thousand pounds	Mid/south zones sum thousand pounds	Southeast monthly averages (1995-96 data): Month	Average price
Jan-95	37.416	97.91	36634						
Feb-95	94.170	100.21	94365						
Mar-95	106.278	93.98	99877						
Apr-95	115.542	90.47	104534						
May-95	124.370	95.16	118355						
Jun-95	366.320	95.11	348419						
Jul-95	352.073	102.27	360057						
Aug-95	70.351	116.25	81784						
Sep-95	197.169	98.23	193676						
Oct-95	61.894	89.30	55272						
Nov-95	128.053	82.65	105841	399	13.600		13.600		
Dec-95	78.540	83.13	65293	1202	48.060		48.060		
Jan-96	56.112	81.00	45452	721	38.650		38.650		
Feb-96	35.416	82.67	29278	542	32.300		32.300		
Mar-96	105.449	79.03	83332	807	43.050		43.050		
Apr-96	121.578	80.52	97889	1128	47.950		47.950		
May-96	121.763	79.82	97193	1426	53.140		53.140		
Jun-96	171.567	85.32	146376	1821	48.150		48.150		
Jul-96	34.117	87.03	29693	1363	41.705		41.705		
Aug-96	14.680	86.98	12769	1526	46.950		46.950		
Sep-96	66.386	89.68	59536	1595	49.000		49.000		
Oct-96	37.392	87.37	32670	1079	32.635		32.635		
Nov-96	25.221	89.94	22684	960	26.800		26.800		
Dec-96	40.842	90.94	37143	1608	62.830		62.830		
Jan-97	57.566	91.75	52817	1580	72.020		72.020	1	91.85
Feb-97	59.171	91.51	54150	1202	57.100	6.712	63.812	2	91.10
Mar-97	129.941	90.24	117261	1288	58.920	15.666	74.586	3	87.75
Apr-97	109.622	82.67	90622	1417	62.900	24.980	87.880	4	84.55
May-97	178.535	81.26	145074	2003	84.872	108.388	193.260	5	85.41
Jun-97	130.865	78.22	102364	1096	43.580	54.773	98.353	6	86.22
Jul-97	103.463	81.06	83864	1652	60.648	52.990	113.638	7	90.12
Aug-97	67.434	94.98	64049	1792	63.035	15.760	78.795	8	99.40
Sep-97	53.241	93.89	49988	1484	55.330	21.240	76.570	9	93.93
Oct-97	53.660	92.98	49891	1439	49.041	15.927	64.968	10	89.88
Nov-97	59.287	93.66	55527	766	24.500	17.667	42.167	11	88.75
Dec-97	29.396	95.18	27979	874	29.950	9.595	39.545	12	89.75
Jan-98	42.565	96.73	41174	937	36.130	18.480	54.610		
Feb-98	62.392	90.00	56153	1182	45.070	28.697	73.767		
Mar-98				1124	43.630	4.400	48.030		
Apr-98				455	17.900		17.900		

Price (southeast) = f (landings, southeast)
Regression Output:

Constant		89.0826
Std Err of Y Est		7.8372
R Squared		0.0083
No. of Observations		38
Degrees of Freedom		36
X Coefficient(s)	0.0092	
Std Err of Coef.	0.0168	

Landings (mid zone) = f (traps, mid zone)
Regression Output:

Constant		6.3781
Std Err of Y Est		8.2863
R Squared		0.7331
No. of Observations		30
Degrees of Freedom		28
X Coefficient(s)	0.0329	
Std Err of Coef.	0.0037	

Traps (mid zone) = f(price, southeast)
Regression Output:

Constant		579.6558
Std Err of Y Est		403.3472
R Squared		0.0117
No. of Observations		28
Degrees of Freedom		26
X Coefficient(s)	7.6463	
Std Err of Coef.	13.7631	

Figure 1.--Golden Crab Landings & Exvessel Prices

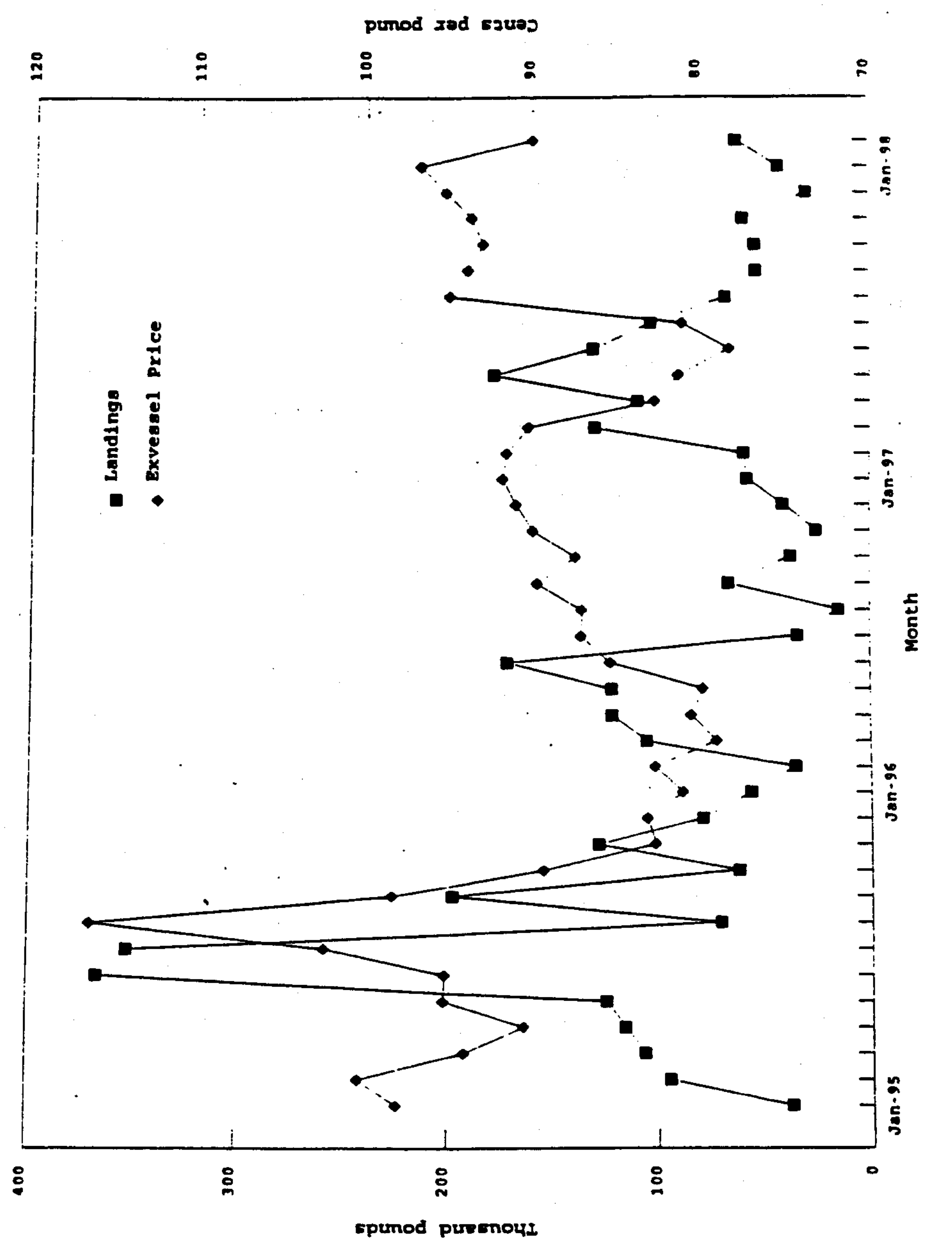
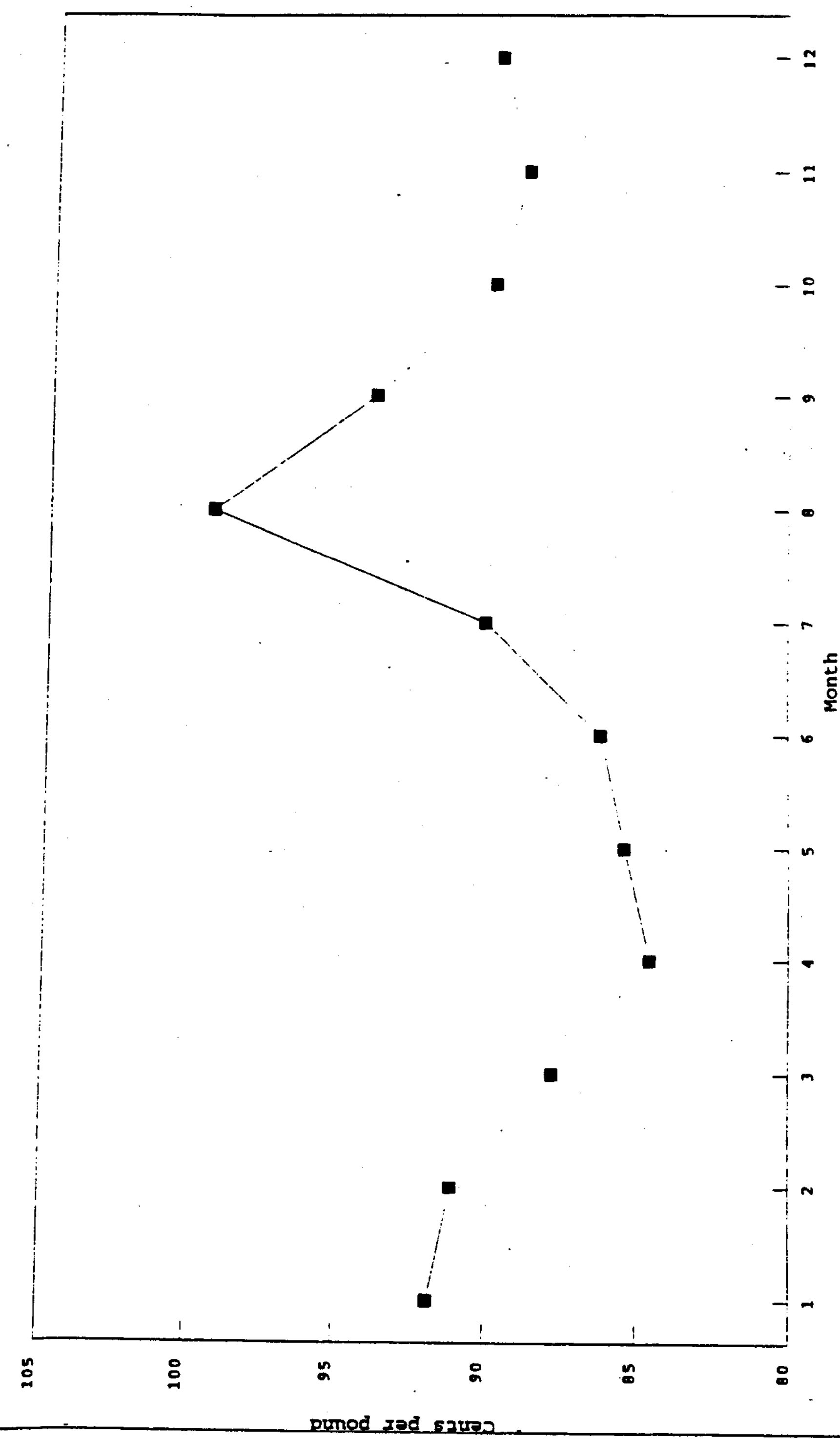


Figure 2.--Golden Crab, Averages for Exvessel Price by Month
(Data for Jan. 1995 to Feb. 1998)



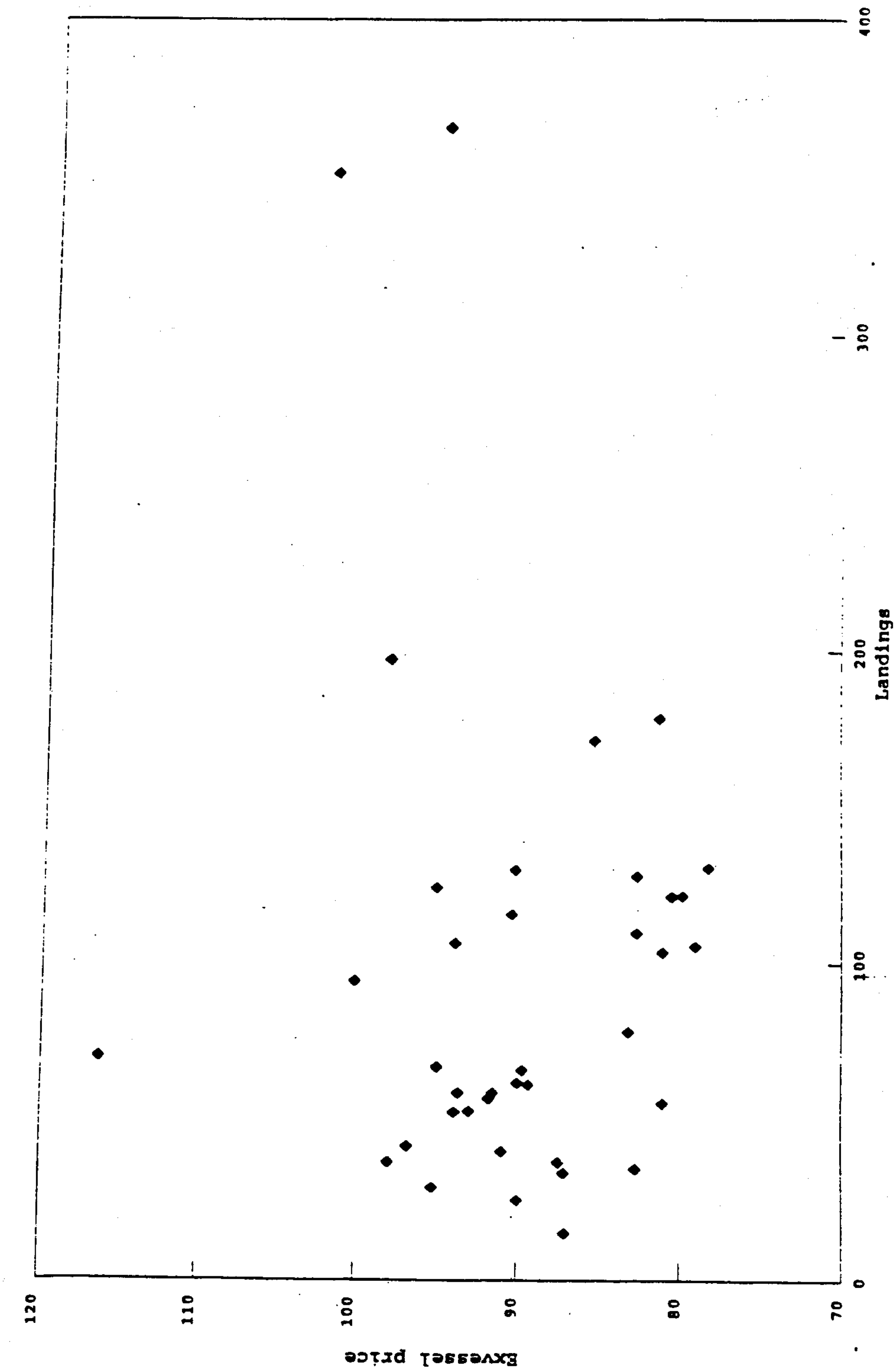


Figure 3.--Southeast Landings and Exvessel Price for Golden Crab
(Data for Jan. 1995 to Feb. 1998)

Appendix I. Golden Crab Progress Report (SERO-ECON-98-01)

GOLDEN CRAB PROGRESS REPORT

Prepared by:

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October 1, 1997

SERO-ECON-98-01

At present, there are five or six vessels dedicated to harvesting golden crab full time. One is docking in St. Petersburg, one in Ft. Lauderdale, two in Marathon and one or two in the lower Keys. Two companies are processing golden crabs into frozen cooked sections (clusters).

Golden crab dealers and processors are trying to recruit additional new vessels into the fishery, but without much success. Seasonally, however, several more boats fish for Golden Crab. This occurs between March and July, during the closed lobster season, when lobster boat operators engage in this fishery to supplement their revenues. At that point, the number of boats active in the golden crab fishery reaches about one dozen.

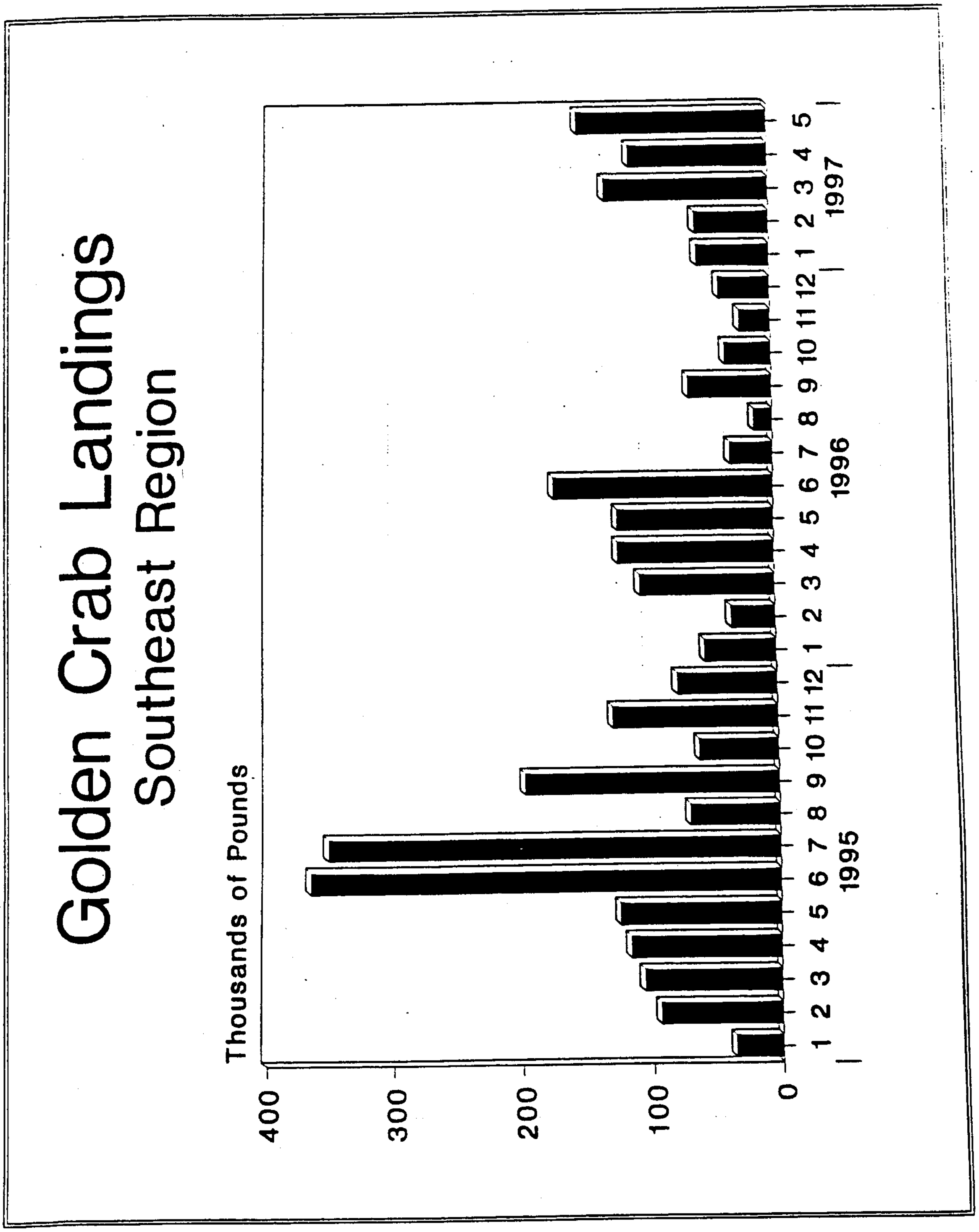
Combined Gulf and South Atlantic landings during the latest twelve-month period (June 1996 through May 1997) totaled 897,000 pounds, down 46% from the previous twelve-month period (June 1995 through May 1996). The total value of crabs landed (ex-vessel) during the most recent 12 months totaled $781,000. This also represents a decline, down 48% from the total value recorded during the previous twelve-month period.

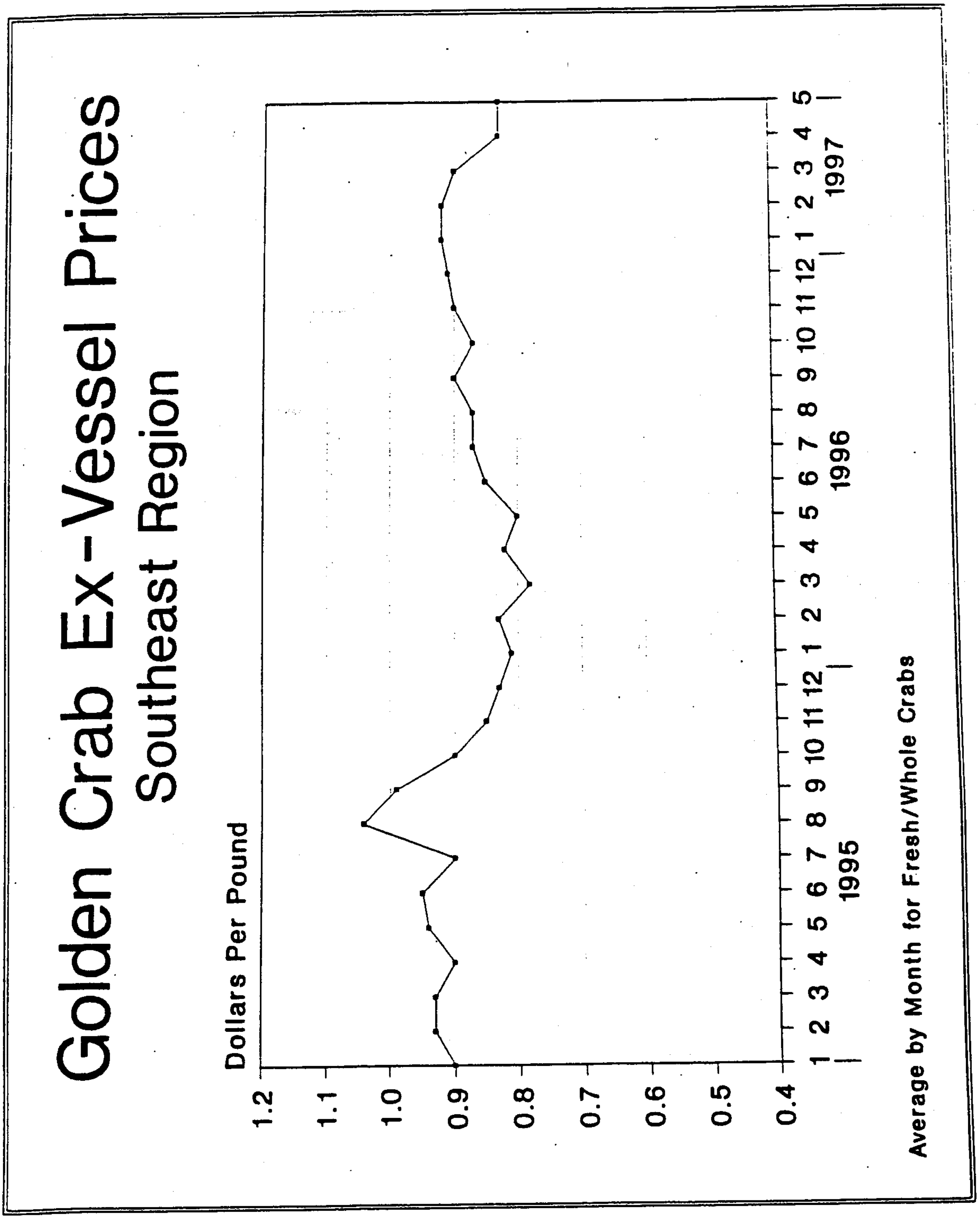
Despite the drop in volume and value, wholesale dealers report that golden crab appears to be creating its own market niche. Repeat business has become more commonplace. This is a positive sign for long term health of the industry. However, lack of product is inhibiting the market from expanding.

An explanation for the lack of production is the difficulty and cost of conducting the golden crab fishery. This fishery requires a sizable investment of special gear, including trap long lines, traps, buoys, and on-board holding facilities that will keep crabs alive. Furthermore, the deep water nature of the fishery can result in lengthy trips (primarily for those vessels fishing off Florida's West Coast), the need to operate in adverse sea conditions, and dealing with strong currents that may submerge the locator buoys for the trap longlines.

Ex-vessel prices are an important factor in attracting vessels to any fishery. Ex-vessel prices for golden crabs have averaged $.83 per pound for the last two months (see attachment). This can be compared to monthly ex-vessel prices of $.90 to $1.04, received during the spring and summer of 1995, when the number of active vessels was estimated at 20 to 25, including several large Alaskan vessels.

Ex-vessel prices for golden crab are being depressed by the abundant supplies of other large crabs, primarily snow crabs


Golden Crab Landings
Southeast Region
Thousands of Pounds
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12
1995
1 2 3 4 5 6 7 8 9 10 11 12
1996
1 2 3 4 5
1997


Golden Crab Ex-Vessel Prices
Southeast Region
Dollars Per Pound
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
1 2 3 4 5 6 7 8 9 10 11 12
1995
1 2 3 4 5 6 7 8 9 10 11 12
1996
1 2 3 4 5
1997
Average by Month for Fresh/Whole Crabs

Appendix J. New Fishery Awaits Management and Fishermen (Fathom Vol.7 No.1)

Crabs Offer Golden Opportunity

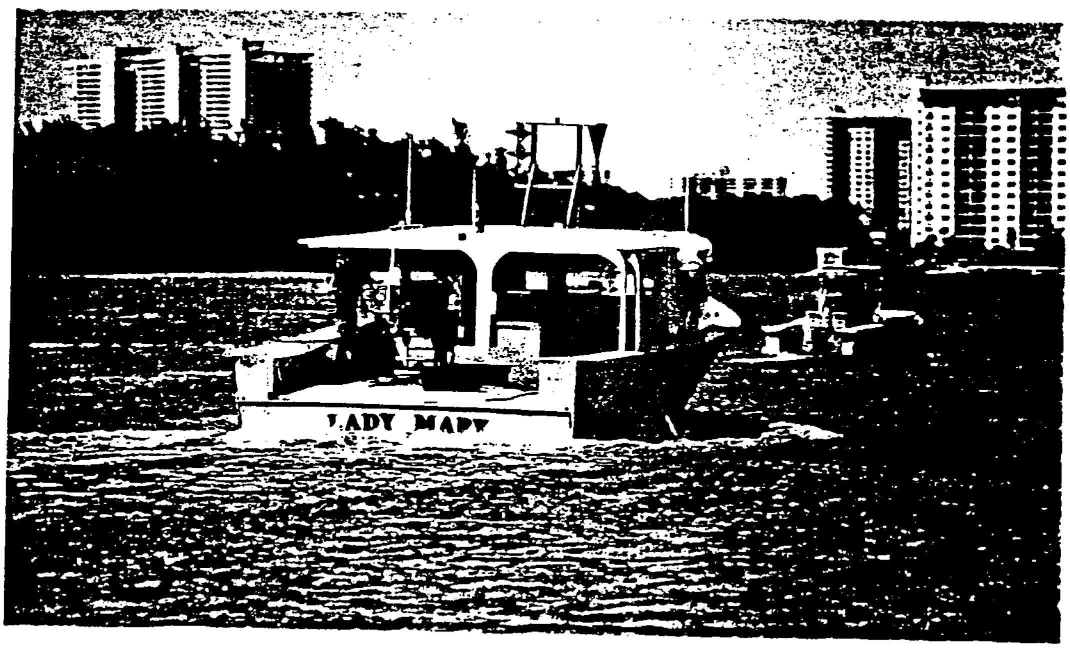
NEW FISHERY AWAITS MANAGEMENT AND FISHERMEN

By Jay Humphreys

In the four a.m. darkness, the gentle throb of the Lady Mary's diesel engine echoes softly from the high-rise office buildings and apartment complexes lining the intercoastal waterway. In a few hours, the streets of Fort Lauderdale will be filled with snarling traffic and harried commuters rushing to their desks. By then, the boat's captain and two-man crew will have left the city far behind in their pursuit of one of the sea's newest and most promising catches--the golden crab.

"We've been catching these crabs full time for a little more than three years," says Richard Nielsen, Jr. as he deftly guides the Lady Mary down the center of the canal. "I guess that makes us the most experienced golden crabbers in the business."

Nielsen explained that, like many things in life, he and his family's dedication to golden crab fishing was more a matter of necessity than design. Years of fish trapping came to an end at midnight on December 31, 1991, when new regulations prohibiting the traps took effect. During the previous ten years, the Nielsens had learned a lot about where to find golden crabs because the little known crustacean had often come up in their fish traps. It didn't take the Nielsens long to switch from fish traps to crab traps.



"Fish traps were outlawed as of January 1, 1992," Nielsen said. "That's the day we became full time golden crab fishermen."

A Tough Job Gets a Little Easier

Getting into the golden crab business is not easy, Nielsen explained. Not only is the right kind of gear required, a golden crab fisherman also has to find the crabs and to do that he has to look in deep water.

"These crabs are literally deep sea creatures," Nielsen said. "They live more than 1,000 feet down and the job of handling traps at that depth, especially when you have to deal with the strong Gulfstream Current, can be exhausting, as well as frustrating. We nearly starved the first year. The second year was a little better and by the end of the third year, we had pretty much figured out how to squeeze a profit out of the fishery."

In addition to the lack of information about the crabs and difficult fishing conditions, the fishery has been plagued by another problem--marketing. The Nielsens have worked with Sea Grant and USDA to develop a market for the crab. So far, their major purchaser has been the Rustic Inn, a local restaurant that specializes in the crab. The rest of the catch is processed, frozen and shipped to traditional wholesale outlets and supermarkets. Local interest in the golden crab among seafood lovers has increased tremendously and recent drastic declines in the snow crab and king crab quotas in Alaska have stirred national and international interest in the new fishery.

"This fishery is ready to take off–all of a sudden it's the thing to do," Nielsen said. "There are so many displaced fishermen due to the near collapse of some traditional fisheries and new restrictions on gear. They are looking for a new fishery and that's why we've gone to the South Atlantic Fisheries Council and asked them for a limited entry status for the fishery. Without that sort of control, this fishery could be easily over exploited."

Crab Provides Unique Management Opportunity

The golden crab fishery presents the South Atlantic Fisheries Management Council with a unique opportunity to put management tools in place virtually at the opening of a fishery. In the past, most management actions have come well after a fishery is on its way to being overfished.

"There's a big market for crab worldwide and that's going to put a lot of pressure on the golden crab fishery," said Richard Nielsen, Sr., the father of the Lady Mary's captain and first mate, and in many ways, the father of the golden crab fishery. In a dockside interview, he offered his views on what the future holds for the fishery.

"Don't get me wrong," Nielsen senior said, "the coming pressure on the golden crab fishery is a good thing. Fishermen are up against the wall financially and this is a new species with lots of potential. We probably have a two-year window of opportunity for the golden crab to establish itself in the marketplace before Alaskan crabs return. My primary concern is to get some regulations in place for this fishery as soon as possible to protect it for future generations."

Working with the Council, the Nielsens have helped shape proposed regulations for the fishery. Some of the key features are: no taking of female golden crabs, an opening to allow juveniles and smaller females to escape from the traps, and an escape hatch to allow all trapped crabs to free themselves if the trap becomes lost. This would eliminate the so-called "ghost traps."

"The Council has really gone along with us in every way to get the right kind of regulations in place," Nielsen said. "I feel really good about their interest in the crab and the professional way in which they have approached managing the fishery. Not only will regulations protect the fishery, it will give the Council a head start on managing it so future regulations should seldom be needed."

Nielsen also had kind things to say about Florida Sea Grant's role in discovering and developing the fishery.

"Sea Grant has been in this with us from the very beginning," said Nielsen. "In fact, it was Sea Grant that really got both the scientific and fishing communities interested in the crab. Sea Grant researchers went out on our boat with us and that was a great help to us in learning more about the crab."

Nielsen also credited Frank Lawlor, the Sea Grant marine agent working that part of Florida's coast, with giving him an understanding of how regulations are written and introduced. "Frank has helped us all along the way," Nielsen said. "He has been our interpreter of government regulations, as well as being the guy who put all the meetings together and organized us so we could get this work done in a timely manner. Without his help and encouragement we may have given up a long time ago."

Public hearings on the proposed regulations will be held through August. At that time, the Council will make its decision on the fishery and it will be forwarded to the National Marine Fisheries Service for a final ruling late this year or early in 1996.

Crabs Ho!

Back aboard the Lady Mary, conversation and comfort are reduced to a minimum as the boat moves through Baker's Haulover and meets the open sea. For the next several hours, the boat parallels the shore, rocking just beyond the surf rushing toward the world famous sites of Miami Beach. Even in April, the subtropical morning is uncomfortably warm. The sun slips above the horizon and gives a sparkling glow to the spray tossed high by the Lady Mary's crashing bow. It is apparent to everyone onboard that Florida's sunny warmth will be with them throughout the day's work.

It's a long run out to the traps, but not nearly as far as the trip made by the two golden crab boats operating in the Gulf from ports on the west coast of Florida. For them, the round trip out to the deep water and their traps can easily take 30 hours. By 6 p.m., 14 hours after casting off, the Lady Mary should be back at her berth.

Finally, Richard Nielsen pulls the throttle back and the boat begins to wallow in the trough of brilliantly blue water. Using only LORAN and depth finder, Nielsen has brought the boat to the spot where they had put down a trawl of 30 to 35 traps nearly 11 days ago. Normally, the traps are left for about five days but a trip to Savannah to attend a South Atlantic Fisheries Management Council meeting has delayed the recovery.

Once snagged, the line is quickly fed into the boat's portside hydraulic hoist. Recovery of the traps is surprisingly quick and soon the first trap breaks the surface. Inside, several golden crab seem almost pure white in the bright sunlight. It takes several seconds to realize that the crabs are indeed golden, or at least a warm, buff color. The trap is quickly emptied, the crabs are stored on ice,

The traps are lifted onto the Lady Mary's deck (left). Once the crabs are removed from the traps (right), they are stored on ice for the trip back to shore.

and the next trap is ready to be emptied.

"The crabs are pretty lethargic when they first come up," said Dave Nielsen, the youngest Nielsen crewmember. "I guess the change in temperature causes that...and there's also the change in pressure for them to deal with. The water where these crabs live is 40-45 degrees and we've just pulled them up through the warm Gulf Stream. But what they really object to is the light. After we get them in the shade and on ice, they recover completely."

Recovery of the traps, removal of the crabs, and dropping freshly baited traps takes less than an hour to accomplish. Then, the boat heads for the next trap location. Typically, the Nielsen's keep three trawls set at all times. And, although Richard Nielsen doesn't want to reveal the exact location of where his traps are set, he does say that experience has taught them that the best place to find golden crab is in water more than 1,000 feet deep and on a bottom made of clay covered with sand.

Finishing the Job

The return trip brings the Lady Mary back into Fort Lauderdale just as the evening rush hour traffic begins to build along the streets and highways running beside and over the intracoastal waterway. Except for general clean up duties and securing the boat at her berth, the crew is finished for the day--catching, unloading, and transporting the crabs all in one day is largely beyond the limits of human endurance. Instead, the iced catch is left aboard the boat until 7 a.m. the next morning. Then, captain and crew return and load the live crabs into a waiting tractor trailer. From there, the truck takes the crabs to a new golden crab processing plant located at Marathon in the Florida Keys.

The Nielsens agree that despite the early setbacks, they are glad they're golden crab fishermen. Not only do they feel that they may be on the threshold of opening up a new, largely untapped, and potentially valuable fishery, they also get a great sense of pride from knowing that they are truly the pioneers of golden crab fishing. With the proper management and marketing, the next few months could easily usher in the golden age of golden crabs.

MEET THE GOLDEN CRAB

Although the golden crab, *Chaceon fenneri*, first appeared in scientific collections as early as the late 1800's it was not until nearly 100 years later that it was recognized to be a distinct species. During the 1980's, Florida Sea Grant researchers and extension personnel first became interested in the new crab's potential as a commercial market. Due to their work, including three research projects and a major workshop held in 1990, interest in developing a golden crab fishery began to grow.

Dr. Bill Lindberg, a Sea Grant researcher at the University of Florida's Department of Fisheries and Aquatic Sciences, headed two of the early projects devoted to the crab--a survey conducted by a deep diving submersible and a regional trapping survey--to determine how many there are and where they can be found.

"The golden crab is a large crab--in a fishery sense they are similar to the king crab," Lindberg said. "But in many ways, they are quite distinct."

For instance, Lindberg explained, the crabs are thought to live as long as 35 years and may take 6-7 years to reach maturity. They live at depths greater than 1,000 feet and are found in the Atlantic and in the eastern Gulf of Mexico on the Upper Continental Shelf. In fact, the largest concentration of female golden crabs was found in the northeastern Gulf west of Tampa. The proportion of females to males declined from that point southward, around the southern tip of Florida and up the eastern side of the peninsula.

"Based on what we know, the golden crab fishery has potential for commercial success," Lindberg concluded. "But prospective crabbers should be aware that the crab's low reproduction rate means the fishery could be easily overfished. In addition, working the traps in deep water is not an easy job."

Appendix K. Golden Crab: Growing a Fishery the Right Way (National Fisherman, September 1995)

Golden crab:
growing a fishery the right way

When fish traps were banned off Florida in 1992, the Nielsen family lost its livelihood. Turning their attention to golden crab, they helped pioneer a promising new fishery. By Hoyt Childers

Crewmen Tom Gagnon (left) and David Nielsen remove golden crabs from a trap while Timothy Sandler (behind) prepares to rebait the gear.

Photographs by Hoyt Childers

Capt. Richard Nielsen Jr., a great bear of a man, plants himself like a tree at the wheel of the crabber Lady Mary and deftly works the throttle and hydraulics. Slowly, the 2 1/4-mile trawl line begins to snap and pop and complain through the hauler, shouldering the strain of lifting traps loaded with golden crab from 130 fathoms.

The first trap breaks the surface and stops right at the hauling block as Nielsen cuts the power. His brother, David, grabs the trap with a hook and swings it onto the wood-surfaced working rail. He muscles the trap sternward where he and two mates empty it of two dozen or so large, buff-colored male crabs before rebaiting and sliding it to starboard, ready to be dropped over the open stern at the end of the haul. It's all over in three minutes or less, and then David is swinging another loaded trap on to the rail.

Richard's hands move smoothly from throttle to wheel to hydraulic controls as he keeps the Lady Mary in proper position relative to his trawl while 15- to 20-knot winds, strong Gulf Stream currents and messy, quartering seas threaten to make a shambles of his trawl line and traps. Occasionally, the line slips off the hauling block or snaps with a loud bang out of the hydraulic sheave.

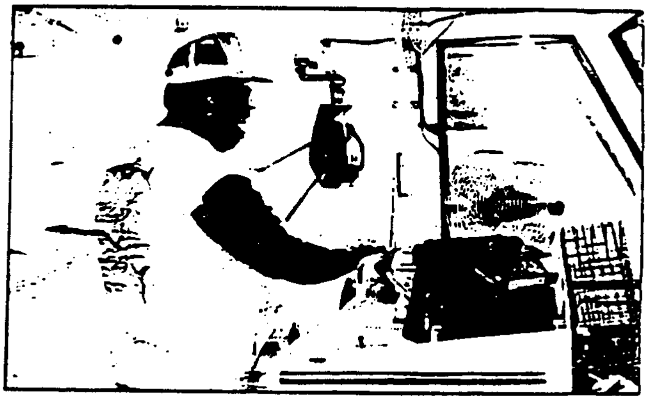
Nielsen seldom breaks rhythm as he throws a few coils of line overboard to gain slack and slips the line back over the outboard block or takes a quick turn around the fairlead and snaps the line back into the still-spinning hauler.

By the time the Nielsens have hauled a few more traps, they know it's going to be a good day. That means a lot when your workday begins long before dawn and could run to midnight. Good prospects also mean a lot when the news in commercial fishing has been bad for years — when your back has been against the wall for a long time.

This trip began several hours earlier at 4 a.m. when Capt. Nielsen eased the 51' Lady Mary out of Griffin Marina, her 380-h.p., turbocharged Volvo diesel a subdued mutter. The Lady Mary is the biggest boat in the marina, and it's a very tight fit. All around are pleasure yachts and sportfishermen.

The trip to the crab grounds takes three to four hours, a good portion of that time navigating "No Wake" zones as the Intracoastal Waterway threads its way through downtown Ft. Lauderdale and north Miami. It's an odd sensation, rumbling along in the predawn dark in this no-nonsense workboat, watching an immense forest of dark office buildings, resort hotels and high-rise condos slide by.

Capt. Richard Nielsen Jr. constantly works the throttle, wheel and hydraulics to maintain position while hauling traps from more than 130 fathoms.



The Lady Mary passes marinas that are home to scores of million-dollar mega-yachts but hardly any commercial fishing vessels.

As the Lady Mary eases along in the dark, it's a good time to talk, and Nielsen speaks without rancor of how life in the fishing business has become ever more difficult since his family moved from Massachusetts to Florida in 1964.

He loves the life of a fisherman and has no regrets for himself. "I'm a third-generation fisherman," Nielsen says. "It's a nice way to grow up." Even so, he wouldn't choose to pass his profession on to his children.

"There's no way that would happen," he says. The future is just too uncertain. He would encourage his children to go to college instead of becoming fishermen, if it came to that. Fortunately, he says, he has three daughters who show no inclination to follow in his footsteps, so it's not an issue.

All along the waterway, concrete, glass and pavement have replaced the sandbars, wetlands, pine and cypress Nielsen remembers. And with the development have come the mega-yachts, big money and ever increasing political clout for sport fishing interests. Commercial fishing families like the Nielsens find it increasingly difficult to make a living on an ever-shrinking slice of the pie.

The Last Stand

Now, Nielsen says, the golden crab fishery is a last stand for his family. "This is our future," he says. "There is no other fishery, this is it for us."

It is clear that Nielsen is optimistic about the golden crab fishery and his family's future in it, that he believes this is going to work, even perhaps that it is meant to be.

But come what may, he says he has made his peace within himself over the struggle. That was not always the case.

In January 1992, the South Atlantic Fishery Management Council banned fish traps — the Nielsen's livelihood. They had fought long and hard against the ban, and he had become exhausted by the struggle.

"It cost us $110,000, and we never had a day in court," Nielsen says.

This was the low point of a bad time in his life, Nielsen says, and he had become bitter and angry. He even began to toy with thoughts of some form of civil disobedience to highlight the commercial fisherman's plight. Maybe sinking an old boat and blocking a shipping channel would get some attention. It was scary, he says, to see himself thinking this way.

Instead of blocking a shipping channel, Nielsen returned to the faith and the church he had turned away from some 20 years before, and it changed his life. "I had to just let go of it," Nielsen says of the bitterness and anger that faith replaced. "It helped make me a better person."

Before the South Atlantic council banned fish traps, the Nielsens had been catching golden crab as a sideline and developing their gear and techniques since about 1985 (see *NF*, Oct. '87, p. 8). After the ban took effect on Jan. 1, 1992, they decided to give it a try full-time.

Now, Nielsen says, it is beginning to look like his family can prosper in the golden crab fishery. Sometimes things have a way of working out for the best. He may yet come to thank the South Atlantic council for banning fish traps, he adds half-jokingly.

By now, the Lady Mary has almost completed her urban passage. Nielsen throttles up the Volvo diesel as the boat moves into a channel and begins to meet rougher seas. Occasionally, a blast of salt spray finds the big exhaust stack sprouting from the engine compartment a few feet aft and vaporizes in a slightly acrid-smelling cloud of steam. It's still dark. Heavy spray pounds the black expanse of the 16'-wide windshield time and again as the Lady Mary turns stern-to to the waking lights of Miami and muscles her way into the open ocean. The powerful growl of the big diesel is a comforting sound.

When we approach the deep crabbing waters, David Nielsen and crew members Timmothy Sandler and Tom Gagnon come up from below where they've been trying to catch some sleep and begin to prepare for action. Everybody trades sneakers for white rubber boots.

Picking Up the Trawl

When Richard's loran tells him he's reached his destination, he and David ready a heavy grapple chain to drop over the side. This may be the trickiest operation of the whole trip.

Before the Nielsens can harvest their crabs, they have to find the traps. This is the part that looks like magic to the uninitiated.

Somewhere below, deeper than 800' on the edge of the continental shelf with no connection whatever to the surface, rests Nielsen's 2 1/4-mile-long trawl line strung at 450' intervals with mesh traps measuring 4' x 30" x 18". Each trap might hold 25 lbs. to 50 lbs. of crab at the end of a week-long soak. The wind is blowing 15 to 20 knots, and the Gulf Stream currents are strong and unpredictable. It's looking for the proverbial needle in a moving hay stack — on a grand scale — if you don't know what you're doing.

The golden crab, *chaceon fenneri*, a deep-water, slow-growing species, became the target of commercial fishermen in the early- to mid-1980s. Full-grown males can weigh up to 5 lbs. Above, David Nielsen displays some of the tiny starfish he believes the golden crab may feed on.

The Nielsen brothers drop the heavy grapple over the side, and Richard nurses the Lady Mary along with the throttle, his intuition and the movement and tension on the grapple line telling him what is happening on the bottom. Twice he engages the hydraulic hauling gear with no success. The third time his face lights up and he yells to the crew that he's got it. It's always easier after the first one, he says.

Once the crew has a trap on board, they work quickly to unload it and get the crabs on ice. They throw back as quickly as possible the occasional female or undersized male that hasn't already found its way out of one of two escape holes.

From the very beginning, Nielsen says, they have limited their catch to mature, male crabs. They don't keep females or small males. Each trap has two 3" x 4" escape holes built in, and this effectively limits

Marketing hurdles

When the Nielsens and others first tried to market golden crab commercially back in the mid-1980s, they encountered an unexpected problem. Restaurants and seafood lovers were sometimes willing to give the little-known newcomer a try, but they would cook it and cook it and cook it, waiting for it to turn red when "done" like any other normal crustacean.

When and if they tried to eat it, its overcooked texture would resemble shoe leather. Here's the deal: Cook golden crab and enjoy it as you would any other crab; just don't expect it to turn red.

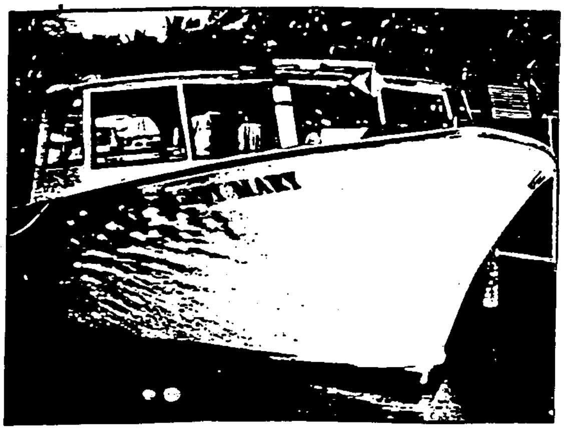
When the Nielsens began targeting golden crab full-time in 1992, the color problem, natural resistance to a new seafood product and other start-up problems made for a very tough year.

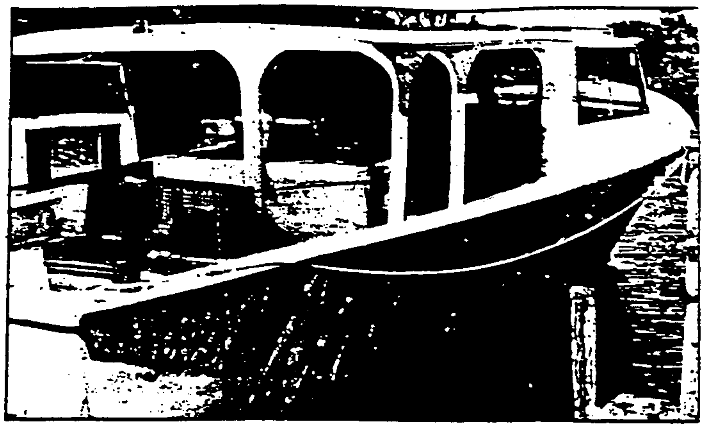
What a difference three years can make. Buyers are now willing to take all the golden crab the Nielsens can haul in.

"In the last few months, the market's really taken off," Richard Nielsen Jr. says. Just locally, they sell 3,800 lbs. to 8,000 lbs. per week. Nielsen says he gets about $1 per lb. at wholesale.

Golden crabs seem to be hardy creatures and can be kept alive like lobsters in holding tanks. If iced immediately when removed from the trap, they can be kept alive on ice for 24 hours or more. They also can be kept frozen after butchering into cleaned halves, or clusters.

— N.C.





Veteran fisherman Richard Nielsen Sr. spent more than two years turning a heavy-duty bare hull into the Lady Mary. A 300-h.p. Volvo diesel powers the 51' fiberglass vessel.

keepers to 1.2 lbs. or larger. Because of the escape holes, very few females or small crabs remain in the traps when they're hauled out.

"We've decided on a minimum size for ourselves," Nielsen says. "Also, bycatch is almost non-existent in this fishery. I can't remember the last time we caught a fish in the trap," he says.

On this particular trip, bycatch amounts to exactly four isopods — foot-long, wiggly, segmented creatures that have crawled the deep bottoms for millions of years. The Nielsens call them "sea roaches" and they stink to high heaven. Nobody needs any urging to get them back over the side as soon as possible.

While David Nielsen and Gagnon empty the trap, Sandler rebaits it with fish carcasses they get from local fish houses. Gagnon packs the crabs in ice in large Igloo coolers or plastic baskets, and David is on his way to hook the next trap that Richard has hauled up. They all work rapidly, moving with the deliberate speed of men who know it's going to be a long day.

Once they have a dozen or so loaded coolers stacked on the open deck, David opens the afterhold and they shift the coolers below decks.

Setting Out

The Lady Mary's stern is open, like many

Restrictions are on the way

"It's difficult to say how many boats are involved in the South Atlantic golden crab fishery." [illegible] Ft. Lauderdale Sea Grant agent Frank Lawlor estimated there were about four boats on the Atlantic side and four on Florida's Gulf of Mexico coast.

The fishery has operated in spurts from North Carolina south around the Florida Keys and into the Gulf of Mexico. What is certain is that the fishery is beginning to get a lot of attention. In a letter they sent to the South Atlantic Fishery Management Council recently, the Nielsens wrote: "Due to the shortage of crabs in Alaska, the troubled fisheries in New England, the troubled scallop and rock shrimp fishery, the net ban in the state of Florida, interest in the golden crab has skyrocketed in just the last couple of months ... It is my understanding that there are three Alaskan crab boats here now. Two in the Gulf of Mexico and one in Cape Canaveral, and several other vessels are just starting to get geared up for this new fishery."

The Nielsens have pioneered development of this fishery and have been at the front of the fight to manage it properly. Up until now, the fishery has been unregulated. Richard Nielsen Jr. says the South Atlantic council has taken warnings to heart and is moving decisively to get sound management practices in place before the fishery gets out of control and goes the way of so many others.

The South Atlantic council has developed proposed regulations for the fishery and is in the process of taking those options to public hearing. Final regulations are expected to become effective in early [illegible].

Among the options being considered are:

— Limiting entry to the fishery based on an April 7, [illegible], control date and on a specified number of licensed vessels for each of several designated fishing areas in North and South Carolina, Georgia and Florida waters;

— Trip limits;

— Limiting types of gear that can be used and depths at which golden crabs can be caught; and

— Limiting retention to large, male crabs.

Nielsen says there are no gear conflicts in the fishery, because nobody fishes for anything else at the depths the crabs live.

— R.C.

New England offshore lobster boats. Crew members move themselves and their gear about with casual disregard for the open stern. With winds approaching 20 knots and the Lady Mary bucking about in seas that even Richard admits are "messy," nobody and nothing gets washed overboard.

Capt. Nielsen says that when his dad, Richard (Dick) Nielsen, completed the Lady Mary in 1989, the open stern was a source of great consternation to local, native-born Florida fishermen. "'How many guys have you lost over the stern?'" they asked, he remembers with a chuckle. Dick remains active in the business but doesn't go out on the boat anymore.

The design makes a lot of sense after the haul when the Lady Mary speeds back across the crabbing grounds and the big traps slide easily off the open stern.

By the time the crew is working the third and final trawl, they know they have a good haul for the day.

"Better than 35 lbs. per trap is considered good," Richard says. His best-ever haul with these traps averaged 53 lbs. per trap. Today, the haul is averaging about 43 lbs. per trap, and he clearly is pleased.

The third set is the best of the day. Every trap holds a good load of the big, pale deep-water crabs.

After the last traps are rebaited and dropped over the stern back into deep water, Nielsen relaxes, turns the helm over to one of his crew members and goes below for his first sit-down meal of the trip — some tasty herb-baked chicken, pasta and vegetables.

Tools of the trade

[illegible]

The Lady Mary heads for port loaded with 4,300 lbs. of crab. Both holds are full of coolers and baskets packed with crabs and ice, and more coolers are lashed and covered with tarps on deck. It's not a capacity load for the Lady Mary, but it's close. It's been a better than average day and a shorter than expected day when the Lady Mary reverses into her slip at 8 p.m. It's still full daylight.

Nielsen is hesitant to make predictions about the future of the golden crab fishery. There's just not enough data available yet, he says.

But he does allow himself some cautious optimism based on the fact that this is an infant commercial fishery that his family has helped pioneer, and that management practices based on sustainable yield principles might well make golden crab a continuing, viable fishery for a score or so of boats. This is a chance to put into practice knowledge gained from mistakes made in other places, he says, most notably the collapse of crab fisheries in Alaska. What's happened in Alaska is "a perfect example of what not to do," he says. This is a chance to do it right from the beginning, he says.

The kind of success the Nielsens are beginning to attain in this fishery feels good, he says. He has buyers waiting for more crab than he can produce, and it looks like 1995 will be a very good year.

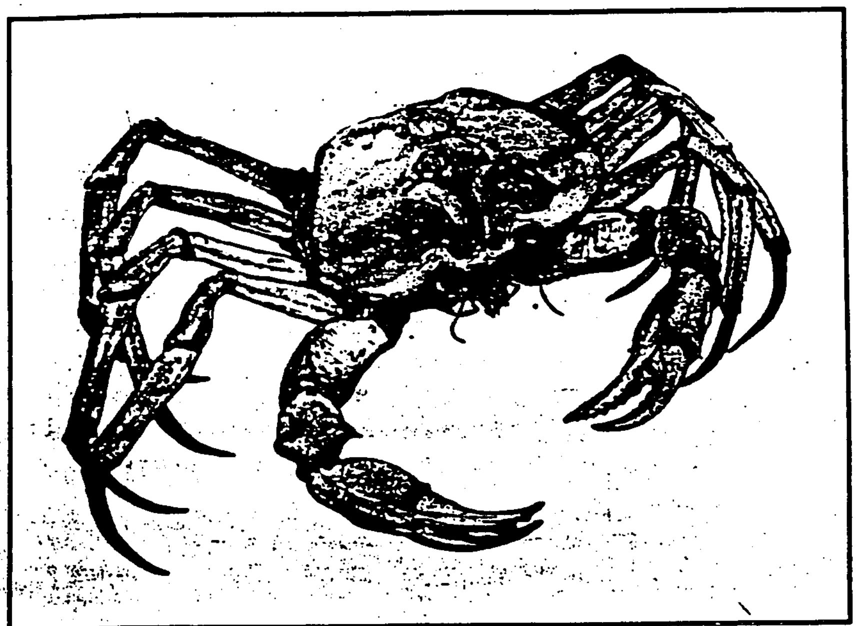
"It's something we've strived for the past 20 years," he says.

Appendix L. Geryonic Crabs and Associated Continental Slope Fauna: A Research Workshop Report (January 1990)

Geryonid Crabs and Associated Continental Slope Fauna:

A Research Workshop Report

William J. Lindberg and Elizabeth L. Wenner
Editors



South Carolina Sea Grant Consortium

Florida Sea Grant College Program

Technical Paper No. 58 January 1990

GERYONID CRABS AND ASSOCIATED CONTINENTAL SLOPE FAUNA:

A RESEARCH WORKSHOP REPORT

edited by

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PREFACE

Considerable research in recent years has been invested in the basic biology, ecology, and fisheries of deep-water crabs, Family Geryonidae. These efforts have been concentrated off the southeastern United States and southwest Africa, following earlier work from the Mid-Atlantic states of the U.S. to the Canadian Maritime Provinces. Species of primary interest have been the golden crab, *Chaceon fenneri*, and the red crabs *C. maritae* and *C. quinquedens*. Only a fraction of recent data has been published. Yet, the many investigators and sponsoring agencies sought to foster regional comparisons, to inform the commercial fishing industry and resource agencies, and to provide guidance for future research investments.

On January 19 and 20, 1989, an invited panel of scientists, fishermen, and Sea Grant Extension faculty met in Tampa, Florida to share their results, conclusions, and latest hypotheses. This report, as a summary of workshop presentations and discussions, is simply a vehicle by which that expertise can be delivered to a broader audience. In due time, the data summarized here should appear in the primary literature. Meanwhile, persons needing greater detail are encouraged to communicate directly with individual investigators.

This international workshop was possible only through the generous sponsorship of several agencies and institutions acknowledged on page iii. We are particularly grateful for the administrative leadership and financial support provided by Alan Hulbert and the National Undersea Research Center, James Cato and the Florida Sea Grant College Program, Margaret Davidson and the South Carolina Sea Grant College Program, and Hugh Popenoe and the International Program of the Institute of Food and Agricultural Sciences, University of Florida. Workshop arrangements were made by Twila Stivender and Monica Lindberg, much to the relief of the workshop co-chairmen, and the report was prepared for publication by Margaret Lentz and Karen Swanson of the South Carolina Wildlife and Marine Resources Department.

Ultimately, credit for this workshop's success belongs to the attendees for their enthusiastic participation. We very much appreciated the collegial exchanges, critical comments, and good

humor. Much remains to be learned about these crabs, and about the ecology of the upper continental slope in general. It is our hope that continued research will give cause for a similar gathering in the not too distant future.

W.J. Lindberg and E.L. Wenner
Workshop Co-Chairmen
April 1989

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STUDIES ON SYSTEMATICS OF GERYONID CRABS

Raymond B. Manning[1]

Geryonid crabs are true deep-water crabs that are found in all oceans except in the eastern Pacific above Chile. They occur in depths from about 100 to more than 2800 meters.

Studies on the geryonids have revealed that the family comprises three genera: *Geryon* proper, with three anterolateral teeth on the carapace, containing two species restricted to the northeastern Atlantic and Mediterranean: *G. trispinosus* (Herbst) (= *G. tridens* (Kroyer)) and *G. longipes* (A. Milne Edwards). Although these are relatively small geryonids, with maximum carapace widths of about 10 cm, they are fished commercially.

Two new genera, *Chaceon* and *Zariquieyon*, both with five anterolateral teeth on the carapace, have been recognized in the family. *Zariquieyon* containing one small species from ca. 2800 meters in the western Mediterranean, was named for R. Zariquey Alvarez. Its size, width about 2 cm, shape, and inflation of the carapace distinguish it from the other geryonid genera. The second new genus, *Chaceon*, was named for Fenner A. Chace, Jr., and contains all of the species now placed in *Geryon* that have five anterolateral teeth on the carapace. It includes 11 named species previously placed in *Geryon*, *G. affinis* (A. Milne Edwards & Bouvier), northeast Atlantic; *G. chuni* (Macpherson), Namibia and South Africa; *G. erytheiae* (Macpherson), Valdivia Bank; *G. fenneri* (Manning & Holthuis), west Atlantic; *G. granulatus* (Ingle), west Africa; *G. granulatus* (Sakai), Japan; *G. inghami* (Manning & Holthuis), Bermuda; *G. macphersoni* (Manning & Holthuis), southwest Indian Ocean and South Africa; *G. maritae* (Manning & Holthuis), west Africa; *G. paulensis* (Chun), south Indian Ocean; and *G. quinquedens* (Smith), northeast Atlantic. Ten new species have been described from this genus: 4 South American, 2 from St. Helena, 1 northeast Atlantic, 1 Mediterranean, 1 from Madagascar, 1 from the central Pacific. Members of this genus are large crabs, with carapace widths ranging from about 7.5 to more than 20 cm.

Characters that are important in the group include: color in life (red, tan, purple/brown, or white; most species are red or tan), size of carapace spines in adults, presence of an outer carpal spine on the cheliped, presence of a distal dorsal spine on

[1]National Museum of Natural History, Crustacean Division, Smithsonian Institution

the walking legs, relative length of the walking legs, and structure of the dactylus of the walking legs, whether laterally compressed or dorsoventrally depressed. Depth range of adults may also be important.

Some generalizations about geryonid crabs are:

Red species often live in deeper waters than tan ones.

Young crabs of some species may live in considerably deeper water than adults. The young of G. trispinosus settle up to 1000 meters below the adults and migrate upwards as they mature.

In some species young crabs resemble adults, whereas in others they may be very different.

Often two or more species occupy the same general geographic range. When this happens they may be separated by depth range of the adults.

Geographic ranges of species tend to be limited. Species do not occur beyond one part of one ocean, and may even be restricted to limited areas, such as undersea banks.

ANIMAL-SEDIMENT RELATIONSHIPS INVOLVING RED CRABS (CHACEON QUINQUEDENS) ON THE SOUTHERN NEW ENGLAND UPPER CONTINENTAL SLOPE

R.B. Whitlatch[2]
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R.N. Zajac[5]

In August 1987, we began a multi-year research program on the southern New England upper continental slope (depth: 750 m) using the submersible DSR/V Johnson-Sea-Link. Our focus was on the role that large, mobile epifaunal organisms have on the biological and physical structure of the seafloor. Specifically, we were interested in examining the red crab (Chaceon quinquedens), one of the most abundant epifaunal species at the study site. We postulate the effects of Chaceon on the seafloor are manifold. For example, redcrab excavation activities are likely to greatly effect the type and abundance of infaunal species and potentially interfere with the natural near-seabed hydrodynamic regime. Alterations in near-bottom velocity profiles can greatly enhance or reduce larval settlement and subsequent recruitment in soft-bottom areas, as well as alter the accumulation and/or removal of organic materials settling on the seafloor. In addition, the activities of these organisms can greatly alter the physical structure of the seafloor by destroying or altering sedimentary texture and fabric, in addition to accelerating rates of sediment mixing (relative to the surrounding seafloor). Such activities can greatly alter the movement of particulate and dissolved materials into and out of the seafloor.

Results of our six-day cruise indicated the study site was extensively bioturbated by the activities of epifaunal organisms. Analysis of videotape transects showed that roughly one-half of the seafloor was covered by a variety of biogenic structures.

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Small depressions and pits (less than 20 cm in diameter) were the most abundant structures, while mounds, caves, tunnels, and troughs were less abundant. Although it appeared that red crabs were the principal biotic modifiers of the seafloor, other species (e.g., galatheid crabs, white hake and flounder) were also acting as primary sediment excavators or modifiers of the red crab-produced biogenic structures. Sediment samples collected from several types of structures indicated significant differences in pore water content and bulk grain-size analysis; particularly in the upper 2-4 cm of the sediment. X-radiographs of the sediment indicated biogenic mixing depths to 20-30 cm, as well as extensive heterogeneity in micro-topographic relief and sediment textural fabric.

Patchiness of biogenic features was quantified over a range of spatial scales. Three of the eight biogenic structures (small pits, large depressions and caves) were aggregated at the scale of a single photograph (3.9 m^2). Measures of patchiness as a function of length scale indicated structure-specific patterns of patchiness on scales of tens to hundreds of meters.

The most abundant epifaunal organisms at the study site were red crabs (8.9 organisms/100 m^2), followed by eelfish (*Aldrovandia affinis*, 6.7/100 m^2), galatheid crabs (*Munida* sp., 2.7/100 m^2), Gulf Stream flounder (*Citharichthys arctifrons*, 1.2/100 m^2), rat-tail fishes (*Coryphaenoides carapinus*, 1.1/100 m^2) and white hake (*Urophycis tenuis*, 0.7/100 m^2). Many of these organisms were found in association with various biogenic structures and their individual dispersion patterns were, in part, auto-correlated with patterns of micro-topographic relief.

Samples of infauna revealed the study site was dominated by polychaetes (65.8% of the total fauna), bivalves (9.8%), aplacophorans (4.7%), and amphipod crustaceans (3.6%). Infaunal densities averaged 198.6 per 225 cm^2, with a relatively high degree of between-sample variation. The fauna was dominated by members of the polychaete families Opheliidae, Paraonidae, Capitellidae and Acrocirridae.

Infaunal samples collected from various biogenic features (burrows, tunnels, mounds and pits) were compared to samples collected from "flat areas" (no structures present). While we are still processing samples, preliminary results indicated no discernible relationship between polychaete, molluscan and crustacean abundance and biogenic features. In addition, no apparent patterns existed between relative abundance of infaunal organisms associated with biogenic structures when compared to flat areas. Infaunal species composition, however, was highly variable between biogenic structures and areas without structures; indicating a high degree of spatial heterogeneity in species' distributions associated with epifaunal-generated disturbance of the seafloor.

Support for shipboard and submersible operations were provided by NOAA's National Underwater Research Center at The University of Connecticut (Avery Point). We thank A. Desbonnet, S. Legler-Brown and R. Petrecca for laboratory assistance.

DISTRIBUTION AND ABUNDANCE OF GOLDEN CRAB, CHACEON FENNERI, IN THE SOUTH ATLANTIC BIGHT

Elizabeth W. Wenner[6]

Exploratory trapping for golden crab, Chaceon fenneri was conducted in 1985 and 1986 off South Carolina and Georgia. Objectives were to determine depth-related changes in abundance, size, and sex composition of golden crab in the South Atlantic Bight; evaluate traps, soak time and gear performance in an effort to optimize fishing technique; and describe adult life history in terms of habitat and reproductive biology. A buoyed system with strings of six traps (three side-entry Fathoms Plus and three top-entry Florida traps) was fished in seven depth strata: 274-366 m (150-200 fm), 367-457 m (210-250 fm), 458-549 m (251-300 fm), 550-640 m (301-350 fm), 641-732 m (351-400 fm), 733-823 m (401-450 fm), and >823 m (>450 fm). A total of 770 traps collected 4387 golden crab that weighed 3936 kg.

Catches of golden crab were related to depth. Catch per trap increased from 2.3 crabs/trap (2 kg/trap) in the shallowest stratum sampled to a maximum of 12 crabs/trap (10 kg/trap) in the 458-549 m depth zone. Catches then declined to <1 individual/trap in deeper strata. Catch per trap of golden crab from this study compares favorably with catch rates reported in the Gulf of Mexico. Distribution within strata was apparently related to bottom type since catches were highest on sediments of silt-clay and globigerina ooze, while few crabs were collected from coral rubble bottom.

Sex composition changed with depth with male crabs significantly outnumbering females in depths from 274-549 m. In the 733-823 m stratum, female golden crab were significantly more numerous than males. Over all strata, male golden crab outnumbered females by 15:1. Although the data suggest segregation of the sexes by depth, it is not known whether seasonal migrations related to mating or spawning occur among golden crab.

The small number of females collected precluded any definitive statements regarding ovarian cycles or spawning patterns. Based on ovarian development, vulval condition, and presence of seminal

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products, it appears that female golden crab reach sexual maturity at sizes between 90-110 mm carapace width. Ovigerous female C. fenneri were collected only from May-August; however, these data do not substantiate a spawning season in the South Atlantic Bight because we were unable to obtain seasonal coverage of all depth strata.

Submersible dives were made in the vicinity of trap sets to provide information on habitat types and densities of golden crab. Observations were made along 85 transects in depths of 389-567 m approximately 122 km southeast of Charleston, SC. Seven habitat types were identified during dives: soft-dimpled ooze (293-475 m); a flat foraminiferan ooze (405-567 m); rippled bottom (419-539 m); dunes (389-411 m); black pebbles (481-564 m); low rock outcrops (503-512 m); and coral mounds (503-555 m). A total of 109 golden crab were sighted within the 583,480 m^2 of bottom surveyed. Twenty-seven percent of the golden crab occurred in the flat ooze which comprised 31% of the total area surveyed. Density (mean no./1000 m^2) was significantly different among habitats, with highest values (0.7/1000 m^2) noted among low rock outcrops. Lowest densities were observed in the dune habitat (<0.1/1000 m^2), while densities for other habitats were similar (0.15-0.22/1000 m^2). The low density (1.9 individuals/ha) of golden crab in our study area and the comparatively high catch per trap suggest that golden crab are drawn to traps from a wide area.

PATTERNS OF POPULATION STRUCTURE AND ABUNDANCE FOR GOLDEN AND RED CRABS IN THE EASTERN GULF OF MEXICO

W.J. Lindberg and F.D. Lockhart[7]
N.J. Blake and R.B. Erdman[8]
H.M. Perry and R.S. Waller[9]

A Chaceon-typical bathymetric pattern of partial sex segregation (females above males) and crab size inversely related to depth was corroborated in the eastern Gulf of Mexico for golden crab, *C. fenneri*, and seems to hold there for red crab, *C. quinquedens*. Variations in that pattern, however, contradicted a simple up-slope migration with age to fully explain the distribution. Instead, sampling at medium-to-fine scales and broad scales helped refine a working model in which females distribute themselves to accommodate successful reproduction, while males distribute themselves to compete effectively for mates. Bottom type, and probably temperature, appear to set limits on distributions.

At a medium-to-fine scale, the bathymetric distribution and abundance of *Chaceon* spp., between 348 m and 787 m, were sampled via submersible transects and longline trapping. In addition to the Chaceon-typical depth pattern, golden crabs were most numerous at depths where most hard bottom was found (i.e., 550 m in Year 1 and 437 m in Year 2), and were seen disproportionately more often on hard bottom regardless of depth. Red crabs were found only on bioturbated West Florida Lime Mud at the deepest contours sampled, 677 m and 787 m. Large *C. fenneri* males and females were most numerous at shallowest depths, but large males were also in low numbers at the deepest contour. Greater proportions of crabs were mated at the two deepest contours, suggesting that large males, once paired, carry females down-slope.

Effects of season, geographic area, and depth on broad-scale patterns of catch per trap and crab size were examined with replicate trap sampling in the northeastern Gulf of Mexico. Golden

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and red crabs differed in geographic as well as bathymetric distributions. Within limits of our sampling, the geographic distribution of C. fenneri was restricted to the upper continental slope off peninsular Florida, while that of C. quinquedens was adjacent to the northern Gulf coast. Neither species was common adjacent to DeSoto Canyon. Regardless of sex, overall average catch per trap was greatest for golden crabs at the southeastern station, while that of red crabs was greatest at the northwestern station. For both golden and red crabs, the proportion of females increased counterclockwise around the northeastern Gulf, within their respective ranges. Male and female red crabs were largest at northwestern stations. Golden crabs exhibited the Chaceon-typical bathymetric pattern, but seasonal shifts occurred in population structure across depths, with some lags between geographic areas. From these patterns and other data, we suggest the Loop Current-Florida Current system has a causal relationship with behaviors affecting distributions of these species.

For golden crabs, in situ density estimates and defined ranges in the eastern Gulf combine to yield a crude estimate of adult standing stock at 7.8 million crabs, with biomass estimated at 6.16 million kg (13.6 million lbs). Alone, a sustained major golden crab fishery in the region does not seem likely. Comparable red crab estimates are not yet possible.

CHACEON MARITAE STUDIES OFF SOUTH WEST AFRICA

Roy Melville-Smith[10]

A number of papers dealing with the biology of Chaceon maritae have been published in recent years, and many of the facts that have come to light in these papers are relevant to the understanding of population trends in the fishery. Some of this information has been combined with new ideas, to explain observed changes in the annual catch rates and size frequency distributions of commercial red crab catches off South West Africa/Namibia since the early 1980's.

Chaceon maritae are slow growing, reaching both maturity and age at first capture by the commercial fishery at 7-9 years (75-90 mm carapace width (CW)). Ovigerous animals are scarce (comprising only 0, 1-0, 2% of all females sampled).

Mature C. maritae females move considerably greater distances than the rest of the population, generally in a northward direction. It is hypothesized that these animals are migrating into central or northern Angolan waters prior to becoming ovigerous. It is further hypothesized that larvae produced may migrate into surface waters and be transported southwards by the Anolan Current, to settle in their highest concentrations between the summer (22 S) and winter (15 S) frontal areas formed by the confluence of the South Angolan and Benguela currents. Catch rates have decreased on the Namibian commercial crab grounds since 1980, but not in a uniform fashion. The northern and central areas of the grounds are highly dependent on new recruits to the fishery (i.e. crabs of 75-90 mm CW). Catch rates in these two areas were reasonably constant up until 1984, but have subsequently eased, whilst oscillating markedly.

By comparison, the catch on the southern Namibian crab grounds (south of 20 S) is less dependent on new recruits to the fishery. Catch rates in this area have fallen drastically since 1980, but do not show the same fluctuations described for the northern areas.

The oscillations observed in the northern and central areas are thought to be due to the delayed effects of depletion of the brood stock by fishing pressure. It is suggested that this

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situation has led to recruitment now being more dependent on environmental conditions (e.g. favorable ocean currents for larval transport) than in the past and that the recent catch rate oscillations reflect year-classes of variable strengths entering the fishery.

The decline in catch rates in the southern area is attributed mainly to the effects of fishing mortality. It is argued that larval recruitment to this area is minimal because it falls outside of the area influenced by the Angolan Current.

FECUNDITY AND REPRODUCTIVE OUTPUT IN CHACEON FENNERI AND C. QUINQUEDENS

Anson H. Hines[11]

I recently compared the covariation of reproductive traits in two species of large deep-sea crabs in the family Geryonidae (Hines, 1988): Chaceon fenneri and C. quinquedens. As in other crab species (Hines, 1982, in press), body size was the primary determinant of reproductive output in the two species. However, their brood masses at 16% and 22% of body weight are considerably larger than the 10% average in most other species and are near the upper extreme of apparently typical interspecific variation (Hines, 1982, 1986, in press), but much less than certain commensal species (Pinnotheridae, Hines, in review; Haplocarcinidae, R.K. Kropp, personal communication). Egg size in the two species is also relatively large, and C. quinquedens has one of the largest reported eggs of brachyurans with marine planktonic larvae. As a result of partitioning the brood into large eggs, fecundity per brood is low compared to many species of comparable size. Comparison of covariation in reproductive traits using ANCOVA to adjust for differences in body weight showed that C. quinquedens had approximately 50% larger volume of the body cavity for accumulation of yolk, resulting in about 50% larger brood mass than C. fenneri. Despite its larger brood mass, egg size in C. quinquedens was about twice as large as in C. fenneri, resulting in about equal size-specific fecundity per brood in the two species. The published literature indicates that both species produce about one brood per year which is incubated over the winter in the northern hemisphere, although C. quinquedens exhibits low levels of brooding year-round. Large yolky eggs in C. quinquedens are likely to contribute to the nutritional flexibility of its larvae (Sulkin and Van Heukelem, 1980), but apparently have coevolved with significant changes in female morphology and reproductive output.

The following table summarized relevant parameters for size and size-dependent variables of reproductive output and fecundity in the two species. Note that both arithmetic means and least squares means are given after adjusting with ANCOVA for differences in body size.

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	C. quinquedens	*C. fenneri*
Body Size		
Carapace Width (mm)		
Arith. Mean	107	124
(range)	(98-118)	(110-143)
Dry Body Weight (g)		
Arith. Mean	68	93
(range)	(48-90)	(74-117)
Volume of Body Cavity (cm^3)		
Arith.Mean	73	62
(range)	(47-91)	(48-73)
LSMean	83	55
Brood Size		
Dry Weight (g)		
Arith.Mean	15	15
(range)	(10-22)	(12-21)
LSMean	17	12
Egg Size		
Diameter (g)		
Arith.Mean	731	568
(range)	(648-760)	(538-588)
Volume (mm^3)		
Arith.Mean	1.636	0.767
(range)	(1.140-1.838)	(0.652-0.851)
Fecundity		
No. Eggs per Brood		
Arith.Mean	162,000	283,000
(range)	(132,000-226,000)	(188,000-371,000)
LSMean	175,000	225,000
No. Brood per Year		
Arith.Mean	1	1
(range)	(0-2?)	(0-1?)

ANNUAL REPRODUCTION IN DEEP-SEA BRACHYURAN CRABS (CHACEON spp.) FROM THE SOUTHEASTERN UNITED STATES

R.B. Erdman and N.J. Blake[12]
H.M. Perry and R.S. Waller[13]
W.J. Lindberg and F.D. Lockhart[14]

Previous studies of deep-sea reproduction patterns indicate that in the absence of changing environmental conditions, continuous cycles are to be expected. Patterns of this type have been reported for deep-sea Chaceon crabs including C. maritae and C. quinquedens. However, studies of C. fenneri from southeastern Florida and the eastern Gulf of Mexico indicate that this species exhibits a pronounced annual reproduction pattern. Additionally, C. quinquedens from the Gulf of Mexico also shows an annual pattern, although more protracted than that of C. fenneri.

Initial studies of C. fenneri were conducted on monthly samples obtained from the commercial fishery centered off Ft. Lauderdale, Florida. Oviposition begins in mid-August and continues through early October with eggs carried for six months until hatching during February and March. A single batch of eggs is produced annually, with brood size highly correlated to carapace width. Samples from this study were limited to depths between 210 and 230 m, thus data on bathymetric distributions were not obtained.

Additional research conducted in the eastern Gulf of Mexico involved seasonal sampling at five areas over depths of 311, 494 and 677 m, and permitted a comparative study of reproduction of C. fenneri and C. quinquedens. Chaceon fenneri was present only in the southern portion of the study area, while C. quinquedens was collected at all areas sampled. Each species was bathymetrically segregated with C. quinquedens found only at 677 m where temperatures were less than 8.0 C. Female C. fenneri were present at all depths sampled but were most abundant at 311 and 494 m. Temperatures at these depths averaged 12.0 and 8.0 C, respectively. Largest females were found at shallowest depths suggesting a reproduction related up-slope migration.

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Both species exhibit an annual reproduction cycle, but differences in the timing of oviposition were noted. *Chaceon quinquedens* carried eggs for nine months following oviposition during early summer, while eggs of *C. fenneri* were carried for six months subsequent to oviposition during late summer. Larvae of both species hatched during early spring.

The annual reproduction pattern shown by *C. fenneri* and *C. quinquedens* infers the presence of subtle "zeitgebers" which serve to synchronize oogenesis, vitellogenesis, oviposition and larval hatching. Variations in reproductive cycles noted may relate to environmental differences that each species experiences over its depth range on the continental slope. The upslope movement by *C. fenneri* suggests reproductive accommodation to environmental conditions that may enhance egg development time and reduce vertical distances for larvae migrating into surface waters. The molting and reproductive cycle of at least *C. fenneri* suggests that although the population as a whole undergoes annual reproduction, individuals within the population may be reproducing biannually.

REPRODUCTION IN MALE AND FEMALE CHACEON

Gertrude W. Hinsch[15]

Specimens from the deep waters of the eastern Gulf of Mexico were collected by commercial fishermen from May 1984 to May 1985 and prepared for study. The carapace width of each specimen received was measured. The reproductive tracts of the 37 males and of the 50 females were dissected out and placed in Karnovsky's glutaraldehyde-paraformaldehye fixative 91965). Tissues were post-fixed in 1% OsO_4, dehydrated in a graded acetone series and embedded in Spurr's low viscosity media (1969). Tissues for light microscopy were fixed as above and embedded in Polyscience JB-4 embedding media, sectioned on a JB-4 microtome, mounted on glass slides and stained with toluidine blue. Tissues fixed as above were critical-point dried, dehydrated, coated with gold-palladium and viewed with a Zeiss Novascan scanning microscope.

Mature male Chaceon fenneri are larger than mature females (9.5-14.5 cm vs 13.5 - 18 cm). The reproductive tracts are typical of brachyuran crustaceans. Analysis of light and electron micrographs suggest that in specimens of C. fenneri from the Gulf of Mexico a single reproductive season exists.

In the male, the testis and vas deferens is much reduced in size and contain primarily spermatogonia and sustentacular cells during the late spring and summer months. Beginning in September - October numerous acini of the testis become filled with spermatocytes in various phases of meiosis. As the season progresses the acini become filled with more advanced stages of spermatogenesis until they become filled with mature sperm in January - February. While it is possible to see a few acini with different stages at all times, most of the acini contain more advanced stages with progression of the season.

The anterior portion of the vas deferens contains some spermatophores at all times. However, beginning in January it begins to swell. By March the middle and posterior regions of the vas deferens become swollen with seminal products as well. The anterior vas deferens produces the wall of the spermatophores which then become surrounded with seminal fluids produced in the middle vas deferens. As the number of spermatophores increases in the

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anterior region, some may also be seen in the middle region. The posterior region of the vas deferens produces an additional seminal product which is added to the contents of the anterior and middle regions at the time of copulation. Copulation appears to occur during March and April after which the reproductive tracts return to the reduced size seen during late spring and summer.

The spermatophores of *Chaceon fenneri* contain several sperm. These are typical brachyuran sperm with several small and long nuclear arms. The wall of the spermatophore differs from that of most brachyurans in having two layers. No noticeable difference can be observed between sperm of *C. fenneri* and *C. quinquedens*.

The fully developed ovary of the female is purple in color. Mature females begin oviposition in September - October. They release their larvae during February - March. This suggests an approximate six month brooding period. Females with developing broods will have ovaries of various size and color indicating that vitellogenesis takes place concurrently with embryonic development of the eggs in the brood pouch.

Other females collected during the late winter - spring months also exhibit ovaries at various stages of development. The seminal receptacles of mature females appear small in size from May to February. Swollen seminal receptacles have been found in females with hatching embryos or egg membranes attached to their pleopods. Females with ovaries in the early stages of development also appear to have swollen seminal receptacles at this time. Analysis of the contents of the swollen receptacles showed quantities of a translucent material as well as a white aggregate. The translucent material resembles that of the posterior vas deferens and the white aggregate contains sperm. In April and thereafter, the translucent material disappears from the seminal receptacle although the sperm persist. These sperm are retained until oviposition.

These data suggest that 1) females may mate following the molt to maturity and that then ovarian development commences and continues in these females until the time of oviposition or 2) females are capable of mating in the hardened condition following larval release. It would seem that females might be reproductive for several seasons. The number of barnacles attached to, as well as wear, to the edges of the carapace tend to support this premise. No eggs or egg cases were found on any females collected during April or May.

The progressive changes seen in both males and females of *Chaceon fenneri* thus suggest but a single breeding season.

AN ASSESSMENT OF THE GEORGIA GOLDEN CRAB FISHERY

Drew Kendall[16]

Crabs belonging to the genus, Chaceon, are non-swimming upper continental shelf inhabitants of the world oceans. To date, approximately 20 species have been identified, and it is likely that more will be discovered. Species reported off the United States in the Western Atlantic and Gulf of Mexico include the red crab, Chaceon quinquedens and the golden crab, Chaceon fenneri (Manning and Holthius 1984).

Golden crabs are known to range from South Carolina down the Atlantic Coast of Florida and into the Gulf of Mexico. Although some information regarding red crab biology and exploitation is available, data concerning the golden crab is limited. As a result, the Georgia Sea Grant Program initiated an assessment of this resource.

Eight cruises were made between November 1986 through October 1988 aboard the R/V Georgia Bulldog. This vessel is a 22 meter wood hull shrimp boat which is equipped with a topside mounted longline reel, and an extensive array of electronics.

Basic longline techniques were used to set out the traps. Fish carcasses were used for bait. Soak times were generally 20 hours.

Thirty six sets containing 612 traps were made. Yield from 577 recovered traps was 3025 kilograms of whole golden crabs. Average catch per trap was 7 kilograms. Approximate weight per crab was 0.9 kilograms. The only other animal caught in significant quantities were jonah crabs, Cancer borealis.

Golden crab sexes are distinct. Males are larger and possess a narrower shaped ventral apron. Our data also indicate segregation by sex. A total of 3176 crabs were sexed and measured. These animals were recovered in depths ranging from 240 to 490 meters, average depth about 366 meters. Eighty (2.5%) of these animals were female, and the remainder 3096 (97.5%) male.

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[16]Georgia Sea Grant Extension Program

Carapace widths were measured in a similar manner as with blue crabs, Callinectes sapidus. The size range was 75-195 mm, mean 151 mm, standard deviation 20 mm, and the mode was 160 mm. Assuming that small crabs and females are not trap shy, and that crabs recruit to the gear at 75 mm, this data seems to indicate an old population comprised of multiple year classes. Determination of the number and age of these classes is difficult, since data regarding the golden crab are lacking. However, studies on other species of Chaceon crabs, particularly the red crab suggest that this is an old slow growing population.

An attempt to determine the population density of golden crabs in two areas subjected to continuous fishing pressure was made. A removal method was employed in an effort to accomplish this. The results of this endeavor showed no significant change in crab catch over the course of 3 sets. In fact, catch rates and carapace widths remained almost the same from one set to the next.

There are several possible reasons for this. The most plausible explanation is that golden crabs are drawn to baited traps from a considerable distance. Given the desolate nature of this habitat it may be essential to the crab's survival that it possess the ability to locate food in remote locations, and move towards it.

In conclusion, the potential for developing a commercial fishery for golden crabs off the Georgia Coast is minimal. Long distances to the fishing grounds, uncertain markets for the crab product, and the hostile nature of working in the Gulf Stream pose obstacles which may be difficult to overcome.

RESPIRATORY AND CARDIOVASCULAR PHYSIOLOGY OF CHACEON FENNERI AND C. QUINQUEDENS IN NORMOXIA AND HYPOXIA

R.P. Henry, H.L. Handley, A. Krarup, and H. Perry[17]

Individuals of *C. fenneri* and *C. quinquedens* were maintained in 30 gallon aquaria in 35 parts per thousand seawater held between 5 and 10 C. Prior to experiments animals were fitted with electrodes and catheters and allowed to recover for 24 hours. Small diameter holes were drilled in the carapace on either side of the heart and scaphognathite, and copper wire electrodes were implanted using cyanoacrylate glue and a rubber dam. These were connected to an impedance converter and oscillographic recorder in order to monitor heart rate (HR) and the frequency of scaphognathite beating (Fscaph, ventilatory rate). A catheter was also implanted in a hole drilled in the branchial chamber; it was connected to a pressure transducer and recorder in order to measure branchial chamber pressure (Pbr) during ventilation. Animals were placed individually in 5 L plexiglas flow-through respiratory chambers, and oxygen uptake (VO^2) was measured as the difference between incurrent and excurrent 0^2 concentrations in the water. Heart rate, ventilatory frequency and pressure were measured simultaneously.

In normoxia (140-150 torr) respiratory and cardiovascular values were as follows:

	VO^2 umol 02 gm-1 min-1	HR bts min-1	Fscaph bts min-1	Pbr cm H20
C. fenneri (N=5)	0.0023 ± 0.0005	35 ± 3	28 ± 7	-1.1 ± 0.3
C. quinquedens (N=4)	0.0050 ± 0.0008	38 ± 1	99 ± 9	-1.5 ± 0.2

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ventilatory pauses, characterized by a temporary cessation of scaphognathite activity and hart beat, which are common among many crustaceans, were observed for both species, but they were infrequent. Ventilatory reversals, during which the direction of water flow through the gill chamber is reversed, were also observed occasionally.

The water in the chamber was made progressively hypoxic by bubbling nitrogen through the incurrent channel. As water PO^2 decreased to about 70 torr, both species maintained near normal respiratory rates primarily through hyperventilation. Below 70 torr VO^2 decreased until a critical low PO^2 was reached at which respiration, ventilation, heart rate ceased (25-35 torr for C. fenneri, and 10 torr or less for C. quinquedens). Recovery of C. fenneri after the chamber was flushed with normoxic seawater took approximately 3 hours and was characterized by increased VO^2, hyperventilation, and tachycardia. C. quinquedens recovered much more quickly (usually by 1 hour), and the changes in VO^2, Fscaph, and HR were much less pronounced during that time.

In a second series of experiments pre- and post-branchial hemolyph samples (corresponding to venous and arterial samples) were taken from crabs in normoxia, hypoxia, and recovery, and hemolymph PO^2 was measured. The values for both species are given below:

	Post Branchial PO^2 (torr)	Pre Branchial PO^2 (torr)
C. fenneri (N=5)	88 ± 6	32 ± 6
C. quinquedens (N=4)	63 ± 16	21 ± 10

The arterial-venous difference is maintained in C. fenneri exposed to hypoxia down to a value of approximately 70 torr; below that it is reduced to about 2 torr. A similar pattern exists for C. quinquedens with the exception being that the arterial-venous difference remains higher (4-13 torr) even under extreme hypoxia. It also appears that C. fenneri experiences an oxygen debt in hypoxia, especially at the critical low PO^2 at which it ceases respiratory and cardiovascular activity. Hemolymph lactic acid concentrations more than double (0.76 mM to 1.5 mM) during hypoxia and remain elevated (~2 mM) during most of the recovery period. This does not appear to be the case for C. quinquedens. This animal maintains respiratory activity to a lower critical PO^2, maintains a higher arterial-venous difference in hemolymph PO^2 in hypoxia, and shows no significant lactic acid buildup in the hemolymph either during hypoxia or recovery.

In summary, it appears that _C. quinquedens_ is somewhat more tolerant to hypoxia than is _C. fenneri_. Both species exhibit responses to hypoxia that are typical of crustaceans in general, and which relate more to common body form and morphological characteristics shared with other species than to any specific environment. Neither species appears particularly tolerant or well adapted to hypoxia, but neither do they appear overly sensitive. Both species are remarkably similar to shallow water species with regard to respiratory and cardiovascular adaptations.

RAPPORTEUR'S COMMENTS

COMMENTARY ON CRAB MANAGEMENT AND THE EAST COAST UNITED STATES GERYONID FISHERIES

David A. Armstrong[18]

Crab fisheries comprise some of the richest resources harvested along the United States coastline. In 1988, total landings exceeded 455 million pounds worth over 383 million dollars (NMFS, 1989), and equaled about 25% of the total dollar value of all U.S. invertebrate fisheries. Crabs harvested in the United States comprise some of the most interesting life history, ecological, and reproductive characteristics to be found among managed U.S. species, and yet the nature and extent of management tends to be relatively similar despite great variation in life history patterns.

The geryonid crab conference, convened in January 1989, considered a variety of life history and ecological data for two principal species, Chaceon quinquedens and C. fenneri, and discussed this information in light of the fledgling deep-water crab fisheries situated in the South Atlantic Bight and northeastern Gulf of Mexico. In general, participants at the conference were not overly optimistic about the prospects for large and sustained fisheries for these species because of their deep-water distribution, evidence of infrequent recruitment, slow growth, older age at reproductive and legal size, and fairly low density over extended regions of the species' range.

As background to analysis of Chaceon biology and life history characteristics relative to their fishery potential, a brief overview of other U.S. crab fisheries can serve to highlight approaches used in management for species that vary considerably in their life history characteristics. Many points of contrast and similarity have been reviewed by Jamieson (1986) who divided crab fisheries into nearshore shallow-water species such as Cancer and Callinectes, and deep water offshore species such as Paralithodes and Chionoecetes. In addition to this bathymetric and on/offshore distinction, it is also informative to distinguish crab fisheries based on the extent of management which ranges from fairly passive (e.g. Cancer magister, Chaceon maritae) to highly dynamic (e.g. Paralithodes camtschatica and Chionoectes bairdii).

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Other U.S. Crab Fisheries

In the temperate to subarctic latitudes of the western U.S. there are three principal crab fisheries. The Dungeness fishery ranges from central California to southeast Alaska, and the king and Tanner crab fisheries largely occur in the Gulf of Alaska and southeastern Bering Sea (Table 1). The latter two groups, king and Tanner crab, are extensively and dynamically managed through joint jurisdiction shared by the state fisheries department and the National Marine Fisheries Service (NMFS). As in the case of most crab fisheries, much of the management is directed toward providing safeguards for reproductive effort by excluding females from the fisheries and setting minimum sizes to allow for adequate male reproduction before capture by the fisheries. This tends to highlight a relatively conservative approach to crab management in the sense that no spawner-recruit relationships have been demonstrated for any species of crab in U.S. waters, and this point was emphasized by several of the participants at the workshop for Chaceon as well. Noticeably different about the management approach to king and Tanner crab is the extensive preseason survey undertaken annually by NMFS that results, eventually, in "harvest range" guidelines as the basis for a strictly managed quota system (Otto, 1981, 1986; NPFMC, 1988). Despite prohibition against capture of females, limited fishing seasons (as short as several weeks in the case of king crab), and extensive survey estimates that lead to imposition of quotas, landings for both king and Tanner crab have fluctuated substantially over the last 15-20 years (Table 1). The fisheries for these long-lived species (8-10 years of age for entry in the case of king crab, 6-8 years for Tanner crab) seem dependent on relatively uncommon, strong year classes, and year-class strength is otherwise viewed as dependent on a suite of physical and biological factors that generally lead to poor survival of larvae or young juveniles (see numerous review articles in Alaska Sea Grant Symposia for Tanner crab, 1982; king crab, 1985 and Dungeness crab, 1985).

Dungeness crab is fished extensively from California through British Columbia to southeast Alaska and, over much of its range, has been characterized by a trend of relatively constant cycles of high and low abundance (see reviews by Botsford, 1986; Botsford et al., 1989; Methot, 1989). Management of this species is relatively passive and carried out by state fisheries agencies throughout its range. This approach prohibits capture of females, imposes a minimum size limit of about 165mm carapace width (CW) and enforces a season closure from fall to early winter (Table 1). No preseason survey exists to estimate abundance of Dungeness crab, nor is there

Species	Sex Fished	Size Limit (mm carapace width)	Estimated Minimum Age in Fishery (YR)	Season Closure	Pre-Season Survey	Gear	Range of Landings (over last 15 yrs) (lb x 10^6)	Quota	Comment
Red King Crab[1] (*Paralithodes camtschatica*)	M	165	8-10	Yes	Extensive	Pot	3-130 Bering Sea	"harvest range" guidelines	
Tanner Crab[2] (*Chionoectes bairdi*)	M	140	6-8	Yes	Extensive	Pot	47-146 all Alaska	"harvest range" guidelines	
Dungeness Crab[3] (*Cancer magister*)	M	165	3-5	Yes	Virtually None	Pot	16-60 Cal-Alaska plus British Columbia	None	Pre-season survey for male shell condition only
Blue Crab[4] (*Callinectes sapidus*)	M, F	75-125	2	Yes; variable between states	No	Pot, dredge, trawl, trotlines	40-104 Chesapeake Bay	None	
Stone Crab[5] (*Menippe mercenaria*)	M, F	claws only, propodus >70	2-3	Yes	No	wooden trap	0.5-3.0 Florida	None	
Red Crab[6] (*Chaceon maritae*)	M, F	None gear 100% selective for crab >75mm	6-8	No	No	Pot	7.7-13.1 SW Africa	None	Japanese fishery off SW Africa; age of catch estimated to be between 8-16 yrs. of age
Golden Crab[7] (*Chaceon fenneri*)	M, F	None	?	No	No	Pot	?	None	

[1]Otto 1986; NPFMC 1988
[2]Otto 1981; NMFS Fisheries stats 1983-88, Alaska Sea Grant 1982
[3]Alaska Sea Grant 1985; PMFC 1987
[4]Millikin and Williams 1984; Jamieson 1986; Cronin 1987
[5]Ehrhardt and Restrepo 1989
[6]Melville-Smith 1988
[7]Workshop Participants

Table 1. Representative crab fisheries and comparison of major features of management and landings.

a quota system. All animals of legal size are vulnerable to the fishery and indeed many states are highly dependent upon annual recruitment to the fisheries for the bulk of landings. Despite threefold fluctuations in apparent abundance (more exaggerated in certain states such as Washington where landings have gone from approximately 4 million pounds in 1985 to over 20 million pounds in 1989), populations are not generally viewed as unstable, and such fluctuations in abundance are credited to a variety of physical oceanographic or biological impacts (see review by Botsford et al., 1989).

The dominant crab fishery on the eastern and Gulf coast of the United States is that for blue crab (Callinectes sapidus). This is a fairly complex fishery from a jurisdictional standpoint since in the area of the Chesapeake Bay, several states manage the resource and yet have variable management approaches concerning legal size, season and gear of capture (Table 1). Both males and females may be captured and, at times, even ovigerous females are legal in certain states. As a relatively short-lived species (2 years at legal size), C. sapidus has proved to be a useful model of recruitment variability as explained by physical and biological features of its habitat (e.g. see review by Sulkin and Epifanio, 1986). A range in landings of about 2.5 fold in Chesapeake Bay has been explained by variability in larval recruitment due to features of wind and current transport that affect attendent larval behavior, and the extent and nature of optimal juvenile habitat within Chesapeake Bay.

A unique fishery located in the southeastern United States is that for stone crabs, Menippe mercenaria and M. adina, which is based not on the whole body of the animal as in other crab fisheries, but only on the extremely large chelipeds. This fishery, located primarily in Florida, allows capture of both sexes and requires a minimal claw size of 70mm propodus length. This equates to an age of about 2-3 years depending on sex and is further managed by a closed season designed to essentially protect female reproduction (Table 1; Ehrhardt and Restrepo, 1989). From the 1970's, catch increased from about a quarter to 3 million pounds of claws annually, but has declined somewhat in recent years.

In the case of these species, relatively extensive literature exists on aspects of life history, reproductive biology, general ecology and habitat requirements. Yet despite commercial importance as fisheries - sometimes for many decades - a surprising amount of information is still unknown about patterns of larval transport, habitat requirements as related to potential year class strength, and any spawner-recruit relationship between mature females and any index of juvenile year class success. While not all such information is needed to manage fisheries, biologists are nonetheless often hampered in their interpretation of fluctuations and apparent population abundance because of too little knowledge of many aspects of species biology; eastern United States species of the genus Chaceon represent an acute example of this situation.

Geryonid Crab Fisheries

Before reviewing information concerning eastern U.S. species of Chaceon, it is important to consider biological and fisheries information from the southwest African fishery exploited by the Japanese and targeted on C. maritae (Melville-Smith this proceeding, 1988). This fishery is relatively new, since about 1973, and has been exploited along the southwestern African coast without benefit of management practices. It is essentially driven by economic considerations relative to the size of product that can be economically processed, and the extent of fishing effort deemed feasible and profitable by Japanese fisheries companies.

Several aspects of the species' life history have important bearing on trends in the current fishery data. As is the case with many geryonid crabs, it is a deep-water species distributed from a couple of hundred to 700m in waters that can range from 4.5 to 10.4°C. As a consequence, it is very slow growing and reaches sexual maturity between 7-9 years of age. Both males and females are fished and are susceptible to the fishery from age 7-9, but many may range from 10-16 years of age (Melville-Smith, 1988). Females are mature at a size of 84mm CW but this size may reflect fishing pressure since maturity in unexploited populations was estimated to be about 100mm CW. One dilemma faced by the fishery is that Japanese pot gear uses a 90mm mesh dimension which is 100% selective for crab greater than 75mm CW, about 9mm smaller than the size at sexual maturity (Melville-Smith this proceedings, 1988). Melville-Smith believes that fisheries over much of the range of C. maritae have come to rely excessively on prerecruits of a given year class reaching legal size in a single year. Since the fishery captures such a large portion of females prior to maturity, and since a very small fraction of the female population is ovigerous at any point in time (0.1 to 0.2%; Melville-Smith, 1988) he fears the combined effects may severely impact egg production and consequently larval transport to heavily fished areas off the southwestern African coast. As evidence of this concern, total Japanese landings have declined from 5.97 million kg in 1983 to 4.72 million in 1986. Based on catch rate CPUE, Melville-Smith estimated that the density of Chaceon on African fishing grounds has decreased about 26% over the past six years (Melville-Smith, 1988).

Such trends of decreasing abundance and catch rate in the South African fishery portend negative consequences for the eastern U.S. fishery for Chaceon as well, with potentially more dramatic consequences based on relative densities of the two species. Density of C. maritae has been estimated to range from 40-230 crab/ha based on pot sampling, up to 350/ha based on observations with underwater photography (Melville-Smith, 1985). However, density of both C. quinquedens and C. fenneri, over much of their range along the eastern U.S. and into the Gulf of Mexico has been estimated to be substantially less, although little density information is available. Lindberg (this proceeding) estimated a standing stock of C. fenneri off Florida's Gulf Coast to be about 7.8 million crab (about 13.6 million pounds). Wenner (this proceeding) observed densities of only 1.9/ha from submersible observations of C. fenneri. However, Whitlatch (this proceeding) reported densities of C. quinquedens up to 900/ha off the southern New England coast, and Wigley et al. (1975) estimated densities of 130-380/ha along the shelf of northeastern U.S. Over a distance of more than 700 km they estimated a standing stock of about 43 million commercial size crab (114mm, 4.5 inches CW) which equated to about 59 million pounds total weight.

It seems that estimates of abundance of surplus males greater than 114mm CW suggests the potential for a sustained fishery on C. quinquedens in the area from Maryland to Georges bank. However, since the survey by Wigley et al. (1975) there have not been sufficient studies to indicate whether juvenile recruitment is consistent on an annual basis, the magnitude of natural mortality rates (Melville-Smith, 1988, provides estimates for the African species) and, in turn, estimated survival to legal size. As in the case of king crab in the Bering Sea, it may be that Chaceon is typified by relatively infrequent, strong year classes that could be overly exploited by a directed, open (no harvest quota) fishery.

Fisheries prospects for C. fenneri, the golden crab, in the South Atlantic Bight to the Gulf of Mexico are more tenuous. The species seems distributed at very low densities but has the capacity to locate food and traps over an apparently great distance (Wenner this proceeding, Wenner et al., 1987) which portends rapid depletion in areas heavily fished. Given aspects of both species' life history (reviewed by Hines and others this proceeding) such as deep water distribution at cold temperatures, slow growth and relatively advanced age at maturity and legal size, it seems that high sustained yield is not likely. As in the case of other crab fisheries listed in Table 1, managers could take a conservative approach (as apparently has been done) that allows capture only of males of a size and age beyond reproductive maturity, with the objective of maintaining species reproductive effort quite apart from the knowledge of biotic and abiotic factors that affect year class strength.

In order to provide some likelihood of reasonable annual catch by participating fisherman, managers may want to consider a limited-entry fishery as has been done with a number of Australian invertebrate species. Given the expense of capitalization for such deep water fishing, it seems that fishermen are vulnerable to the vagaries of surplus male abundance which could be quickly reduced by unrestricted participation. Without an annual preseason survey and resultant catch quota at the present, there is no basis to attenuate excessive annual exploitation and spread capture of large males over several years, particularly if year classes reaching legal size are infrequently strong as hypothesized for P. camtschatica in the Bering Sea. Limited entry (and effort) might achieve this goal of more stable yield, although somewhat blindly since state fisheries agencies will likely not conduct surveys to estimate stock abundance as a means to index the degree of annual exploitation by a limited-entry fishery.

Another option as practiced for some west coast Canadian invertebrate fisheries that are not well studied and regulated is that of "boom and bust". So long as rudimentary guidelines safeguard reproductive effort, the fishery is allowed to grow to any size (unrestricted vessel participation) and achieve 100% exploitation as it is able. Eventual decrease in abundance and reduction in landings are consequences to which fishermen must adjust as they either stay with Chaceon spp. or move into other fisheries. Clearly the southwestern African C. maritae fishery is precarious because management guidelines have not been implemented to even safeguard reproductive effort through size, sex and season. In comparison, U.S. Chaceon fisheries can be better managed, but species recruitment success and population dynamics might be such as to provide only a limited and marginal fishery off many states.

RAPPORTEUR'S COMMENTS

Commentary on Life History and Ecology of Deep-Sea Crabs of the Family Geryonidae

Anson H. Hines[19]

Successful management of fisheries sustaining maximum yield requires strategic decisions from accurate knowledge of the basic life history and ecology of target species. In addition, prediction of the impact of fishing activities on the ecosystem depends upon knowledge of the fundamental role of the species in its natural community. For crabs of the family Geryonidae, development of a data base which will allow informed management decisions is inherently difficult because of the depth distribution of the species on the continental slope. Nevertheless, fisheries are developing for geryonid species, and we need to assess our knowledge of their basic biology. In addition, as manned and remotely operated technology has developed, we are increasingly able to examine the importance of these crabs in the continental slop ecosystem as a zone of both fundamental and applied interests.

The workshop on geryonid crabs was convened to assess the state of our knowledge and research progress on primarily two species, Chaceon quinquedens and C. fenneri (the genus of these two species was revised in 1989 from Geryon to Chaceon, see below under Systematics). However, a comparative approach in the workshop emphasized similarities and contrasts among these two species and other members of the family, as well as species of commercial and non-commercial crabs from other families. This readily allowed both scientists and managers to organize data into meaningful patterns, to assess the unique and general features of the particular species, to benefit from the mistakes and successes in management of other species, and to establish research priorities. The workshop also emphasized the need for comparative data over the geographic range of the species, because these contrasts provide insight into the variability and flexibility of the species' biology.

In addition to assessing the systematic and zoogeographic status of the family Geryonidae, considerations of life history and ecology were organized into several subtopics. The topics within life history analysis fell into the sequence of the crabs' life

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cycle of reproduction, development, growth, and maturation. As these topics are aspects of population biology, they led logically into considerations of population stability, dispersal, resource utilization, and sources of mortality. The workshop also considered the crabs' potential as regulators of benthic community structure on the continental slope. The purpose of this commentary is to summarize the discussion, emphasizing the participants' concensus about what is and is not known about the basic biology of the crabs, but it is not meant to provide a comprehensive review of the geryonid literature.

Systematics and Zoogeography. Initially, very few species were thought to comprise the Geryonidae; however, in a recent revision of the family, three genera and 24 species (Geryon with two species, Chaceon with 21 species including C. fenneri, C. quinquedens and C. maritae, and Zariquieyon with one species) are now recognized (Manning and Holthius, 1989). The number of recognized species is likely to increase with additional attention by systematists, ecologists, and fisheries biologists and with new technological applications at more sites. Some of the characters used to distinguish species include phenotypic features, especially color, which some workshop participants believed were too variable within species to be reliable diagnostic characters. On the other hand, the shape (lateral compression vs. dorso-ventral depression) of the dactyls of the walking legs is apparently both a useful diagnostic character for some species and a potential indicator of primary substrate utilization (see Resource Utilization below). The family is apparently widely distributed throughout the world's oceans at depths of 200-1200 m, especially on upper continental slopes. Although some species are small in body size and, through limited sampling, are known only from very restricted geographic ranges, the large size, abundance and distribution of some species indicate that the family plays an important role in the slope ecosystem on a world-wide basis.

Reproduction. Several recent studies have focused on reproduction in Chaceon spp. (Melville-Smith, 1987; Wenner et al., 1987; Hinsch, 1988a,b; Erdmann and Blake, 1988; Hines, 1988), following initial survey work by Haefner (1977) and McElman and Elner (1982). Gametogenesis is similar to that in other species of crabs. Chaceon maritae reproduces year-round, and C. quinquedens exhibits low levels of brooding year-round. However, off New England and Florida C. quiquedens apparently has a winter peak in brooding, and C. fenneri is a distinctly seasonal winter brooder off Florida. Individual females of any of the three studied species probably do not produce more than one brood per year. Also, some evidence indicates that individual brood production may be biennial in C.

fenneri (see Maturation and Mating below). Compared to other species of crabs, egg size in Chaceon spp. is very large, and fecundity is relatively low (100,000 - 400,000 eggs per brood) for such large body size.

Development and Recruitment. Larval descriptions are available for C. quinquedens (Perkins, 1973), C. tridens (Brattegard and Sankarankutty, 1967; Ingle, 1979) and C. fenneri (Perry, pers. comm.). Experiments on C. quinquedens in laboratory culture indicate that these larvae have long developmental times in cold waters (125 days at 6-10°C) but much shorter times at temperatures typical of warmer surface waters (only 23 days at 25°C) (Rosowski, 1979; Sulkin and Van Heukelem, 1980; Kelly et al., 1982). The larvae exhibit considerable "nutritional flexibility" in their ability to develop normally even on relatively poor quality food such as rotifers (Sulkin and Van Heukelem, 1980), perhaps as a result of the large amount of yolk invested in the eggs (Hines, 1988). The larval biology of deep-sea crabs is poorly understood because so few zoeae and megalopae have been sampled in the field (but see Roff et al., 1984, 1986). However, the lab experiments and the few larvae collected in the plankton indicate that development occurs near the surface, as is typical of most crabs. Laboratory studies of larval responses to temperature, pressure and gravity indicate that larval C. quinquedens can migrate vertically through the water column with swimming behavior that allows them to pass through marked thermoclines, which is adaptive for moving early stage larvae up to the warmer, food-rich surface waters and for producing wide larval dispersal in surface currents (Kelly et al., 1982).

Very few small crabs have been collected or observed in the field; and the timing, habitat, and intensity of recruitment are poorly understood. The few small crabs which have been found come from the deepest zones of the species distribution for C. quinquedens and C. fenneri (Wigley et al., 1975). We need to test quantitatively the validity of this observation by trying to determine whether the lack of small crabs observed via submersibles (Lindberg and Lockhart, 1988) and their paucity from trawls is typical, or whether our sampling designs have been inadequate. We need to know whether recruitment is specific to greater depths, or whether recruitment occurs at all depths and small crabs suffer higher mortality at shallower depths.

Growth. Deep-sea crabs appear to be slow growing, long-lived animals. In some cases (e.g., female C. fenneri off the South Atlantic Bight of North America; Wenner et al., 1987), populations exhibit polymodal size-frequency distributions; but it is not known if these modes correspond to year-classes or instars. If the modes are instars, then the number of instars is not unusually large but the molt increment is substantial (40-50% for 100 mm crabs declining to about 14% for 145 mm crabs). If the modes are year-classes, then these are estimates of annual growth but they tell us nothing about the number of instars, although the occurrence of annual molting in females would equate number of post-maturation instars and years (but see Maturation and Mating below). Most populations, especially males, show no polymodality in size structure. Size-frequency analysis of all populations of C. quinquedens, C. fenneri, and C. maritae do show that males grow substantially larger (about 50% carapace width) than females.

Other things being equal, large size at settlement will reduce the time and number of instars required to grow to maturity (Hines, 1986). Size at settlement of the first crab instar is unusually large (4 mm carapace width in C. quinquedens, Van Heukelem et al., 1983, and 3 mm in Geryon tridens, Ingle, 1979) compared to most crab species and is similar to the large first crabs of Ocypode spp. and Cancer magister (Hines, 1986). This large size at settlement may be adaptive for otherwise slow growth to adult size.

Growth has been measured directly in C. maritae (Melville-Smith, 1989) and C. quinquedens (Farlow, 1980; Gerrior, 1981; Lux et al., 1982; Van Heukelem et al., 1983). Farlow (1980) reported molt increments of 8-21% for captive 73-94 mm female C. quinquedens, with no correlation of increment and premolt size. Limited data from field tagging studies of C. quinquedens indicate slow growth and potentially long intervals (perhaps 6-7 yr or more) between molts of larger crabs (Gerrior, 1981; Lux et al., 1982). In C. quinquedens reared through the first 5-6 juvenile instars (about 20 mm carapace width) from larvae in the lab, growth rate was temperature dependent and indicates that 5-6 years would be required to grow to entry into the fishery at 114 mm or about 7-8 years to maximum size of 140 mm (Van Heukelem et al., 1983). In the best analysis of growth in a geryonid, Melville-Smith (1989) used dart tags in epimeral sutures for a mark-recapture study of C. maritae to determine the molt increment and estimate intermolt interval in crabs >60 mm. The molt increment percentage declines with increasing size from about 20-25% at 60 mm to about 15% at 130 mm. Males had larger molt increments than females, and males exhibited a reduced molt increment after maturity at about 93 mm. Females molted only rarely after attaining maturity. Estimated molt intervals for males ranged from about 1.5 yr for 60 mm crabs to 6-7 yr for 130 mm crabs. By combining the laboratory data for early instars of C. quinquedens with the field data for C. maritae, Melville-Smith (1989) estimated the size and age of each instar for

C. maritae, with male maturity occurring at 12 instars, 90 mm, and 9 yrs of age, and maximum growth to 170 mm requiring 16 instars and 33 yrs. Although these estimates for intermolt interval and age are indeed long, some other cold-water species (Chionoecetes spp. and Cancer pagurus) are also estimated to have similar slow growth and long life. The number of instars and molt increments reported by Melville-Smith (1989) for C. maritae are typical for most brachyurans (Hines, unpublished).

Maturation and Mating. Based on growth studies, mature crabs are 5-15 years old or more. Both sexes appear to mature at about the same size, but males grow larger than females. Maturation occurs at about 90 mm in C. maritae, 95 mm in C. fenneri, and 85 mm in C. quinquedens. Although some workshop participants suggested that females exhibit a terminal molt at maturity but males do not, there is no real evidence to indicate a true terminal molt (see recent dispute over this issue for the majid crab Chionoecetes opilio: Conan and Comeau, 1986; Ennis et al., 1988; Donaldson and Johnson, 1988), though molting may be very infrequent (6-7 yr). In C. maritae, mature females have been observed to molt, but it appears that they do so only rarely (Melville-Smith, 1983). Maturation may occur seasonally in C. fenneri and C. quinquedens, which have populations with seasonal reproductive cycles; and maturation may occur all year round in C. maritae, which reproduces year-round. There are few data to test these proposed seasonal patterns.

Because the two sexes of many populations appear to differ in their bathymetric distributions (see below under Resource Utilization), it is not clear how the sexes get together for mating. A seasonal vertical migration by females has been postulated (e.g., Wigley et al., 1975), but little hard evidence is available. Males probably are attracted to mates by pheromones released by the female, as is the case in many other decapod crustaceans including many brachyurans; and based on observation of chemotaxis to bait, the chemotaxis could operate on the scale of tens of meters in appropriate current regimes (Lindberg, pers. comm.).

Observations in the laboratory indicate that mating behavior is typical of other crabs (Elner et al., 1987 for C. quinquedens; Mori and Relini, 1982 for C. longipes; Wenner et al., 1987 and Perry, pers. comm. for C. fenneri) but that doubling up and intromission may last for a long period (11.5 days in C. quinquedens and weeks or more in C. fenneri in the laboratory). Males apparently may mate with intermolt females as well as copulating with newly molted females. With post-copulatory marking analogous to those on Dungeness crabs (Cancer magister) and snow crabs (Chionoecetes opilio), female Chaceon maritae show abrasions on their walking legs from mating embraces, as well as darkened vulvae and abrasions from contact with male pleopods on the ventral carapace under the abdominal flap (Melville-Smith, 1987). While categorization of female vulvae does indicate maturation and mating in other Chaceon spp. (e.g., Wenner et al., 1987), similar mating marks have not been recorded for female carapaces of other geryonids.

In C. fenneri there is controversy over whether females molt and mate annually (Hinsch, 1988a,b) or molt after a brood is released and mate later to produce the next brood in alternate years for a biennial reproductive cycle (Erdman and Blake, 1988; Erdman, in review). Precedent occurs for such a biennial cycle in cold-water for the blue king crab Parlithodes platypus (Jensen and Armstrong, 1989). Obviously, reproduction could occur within the population each year; but with only half of the females producing a brood, the population's egg production would be only half of that if all females brooded annually. As in some other groups of crabs, females may store sperm for prolonged periods, producing one or more broods without additional copulation. However, there are few data to test this, and no one knows if sperm can be stored by a female from one instar to another. Some of these reproductive strategies may be highly adaptive for cold, food-poor waters of the deep sea, where energy for yolk accumulation may be difficult to acquire; and they may also serve to ensure reproductive success when mates are difficult to find.

The length of reproductive life in geryonids is not known, but life spans of up to 33 years have been speculated. No evidence of senility has been found, but most population samples provide too few females to yield adequate analysis of reproductive activity by size (age). Mature males appear to be equally reproductive at all sizes.

Population Stability and Dispersal. Although population densities, sexual composition, and size structure appear to vary significantly in space for C. fenneri, C. quinquedens, and C. maritae, we have very little real data on annual or long-term variation in population abundance. Because of the potential for long-distance larval dispersal, there is concern that recruitment for key fishery locations may depend heavily on reproductive stock under distant management jurisdictions. For example, recruitment for the C. maritae fishery off southwest African waters appears to be derived from stocks to the north. Similarly, Kelly et al. (1982) proposed that larval C. quinquedens are transported to the mid-Atlantic Bight by the Gulf Stream. Although recruitment is poorly understood in any geryonid species, failure to find many small juveniles and comparisons with recruitment fluctuations in blue crab (Callinectes sapidus), Dungeness crab (Cancer magister), snow crab (Chionoecetes opilio), and king crab (Paralithodes spp.) populations suggest that major successful recruitment events occur very rarely; but those recruits may dominate a population for a long period, perhaps 10 years or more.

Movement of some geryonids appears to be substantial and could cause significant dispersal. Despite apparently intensive trapping in some locations (e.g., the C. fenneri fishery off Ft. Lauderdale, Florida), there has been no apparent reduction in crab abundance, suggesting that other crabs are "filling in" from some unknown distance in the surrounding waters. Melville-Smith (1987) reports significant movement of C. maritae in mark/recapture studies off the coast of southwest Africa/Namibia, with differences between sexes. Mature females exhibited significant net movement northward and greater movement than other categories of crabs. Large males moved farther than small males. Over 32% of the recaptured crabs moved greater than 100 km over a period of years of the study. The net rate of movement was only about 0.05 km/day for males and immature females, while mature females moved 0.11 km/day southward compared to 0.46 km/day northward. These movement data may indicate a sexual pattern of migration off the African coast. Lux et al. (1982) found that most net movement was under 20 km for C. quinquedens off southern New England, although some individuals moved as far as 90 km during a 7 year study period. No evidence of seasonal migration was found, and most movement appeared to be up and down the continental slope rather than long-shore.

Stock identification is poorly understood for geryonid fisheries. Because of the potential for wide larval dispersal and substantial benthic movement of juveniles and adults, there is little understanding of any barriers that would serve to delineate biologically appropriate management boundaries or to provide clues about deme size and gene flow. Population size of C. maritae off southwest Africa has been estimated by photography and tagging to be 21.6 and 19.5 million crabs respectively, while trawling underestimates population size at 1.9 million crabs (summarized in Melville-Smith, 1988). Since early population estimates for other fisheries are largely based on trawl or trap data, little trust can be placed on those reports. More recent surveys from submersibles (Whitlatch, unpublished; Lindberg and Lockhart, 1988; Wenner and Barans, in press) give more accurate information for C. quinquedens and C. fenneri, but the geographic extent of those surveys is limited, making it inadvisable to extrapolate population size.

Resource Utilization (depth, substrate, food). Geryonids show habitat partitioning by depth and substrate. The majority of available data is for bathymetric distribution. Chaceon fenneri and C. quinquedens occur at different depth zones in the eastern Gulf of Mexico, with C. fenneri distributed shallower than C. quinquedens (Lindberg and Lockhart, 1988; Lindberg et al., 1989). In addition to interspecific zonation, most populations show intraspecific zonation with the two sexes distributed differently. For C. fenneri, C. quinquedens and C. maritae, females tend to be more abundant at shallower depths (Lindberg et al., 1989; Haefner, 1978; Melville-Smith, 1987), although the few females trapped by Wenner et al. (1987) in the South Atlantic Bight were deeper than most males.

Chaceon maritae, C. quinquedens, and C. fenneri are found patchily distributed on both soft and hard substrates. Chaceon quinquedens appears to be most common on soft substrates, while C. fenneri apparently reaches highest densities on hard substrates (Wenner and Barans, in press; Lindberg, pers. comm.). The laterally compressed dactyls of C. fenneri may be better adapted for hard substrates, while the dorso-ventrallly depressed dactyls of C. quinquedens may allow easier movement over soft substrates (Manning, pers. comm.). The association of these crabs with particular substrates is of particular interest to fishermen, who want to fish high density patches of crabs but must avoid hard substrates which might foul gear.

The diet of geryonids is poorly known. They are often categorized as scavengers that feed opportunistically on bonanzas of carrion deposited on the bottom from overlying waters. The only significant published analysis of stomach contents of crabs not captured in baited traps is by Farlow (1980) for C. quinquedens off southern New England, where the crabs are predators as well as scavengers. Small crabs fed mainly on sponges, hydroides, gastropods, schaphopods, small polychaetes, and small crustaceans; large crabs also took larger prey (including fishes, squid, and Hyalinecia) but it is not entirely clear if these items were scavenged or captured alive. Diel changes in gut fullness of crabs in the field indicate 1-2 peaks of feeding during daylight hours. Crabs about 250 g in weight consume 0.09-0.7 g dry weight of food per day, with much of the food mass as mucus and sediment that may be of little nutritional value. Observations of feeding behavior from submersibles indicates that C. quinquedens may be a deposit feeder to some extent, and that C. fenneri is attracted from considerable distances (tens of meters) by olfactory cues from bait.

Sources of Mortality. Few data are available on sources of mortality for geryonids. Several species of fish are reported to prey upon juveniles (Melville-Smith, pers. comm. for C. maritae), but there are few published records of geryonids in fish stomach contents (Sedberry and Musick, 1978 for the gadid Phycis chesteri on C. quinquedens). Mortality rates from fishing have been estimated at 0.24 males and 0.41 females per year (Melville-Smith, 1988). Other estimates of mortality are lacking.

Community Interactions: Deep-Sea crabs as Predators, Bioturbators, Competitors, and Hosts. Geryonids may have a significant role as a dominant predator in continental slope communities. Analysis of stomach contents for C. quinquedens indicates active predation on a wide variety of infaunal and epibenthic invertebrates (Farlow, 1980). Observations of C. quinquedens off southern New England (Grassle et al., 1975; Haedrich et al., 1975; Whitlatch, pers. comm.) and C. fenneri (Wenner, pers. comm.) off South Carolina indicate that these crabs are major sources of bioturbation in the surface sediments of the slope. Locomotion and active digging in addition to feeding activities appear to disturb and turn over the sediment extensively in areas where the crabs are relatively abundant.

Competition among geryonid crabs is poorly understood. Bathymetric partitioning by C. fenneri and C. quinquedens could result from competitive interactions between these two species in which goldern crabs exclude red crabs from shallower depths. However, C. quinquedens does not move shallower in areas where C. fenneri is absent in the Gulf of Mexico (Lindberg et al., 1989). Off New England, Cancer borealis and Homarus americanus may be competing with C. quinquedens at the shallow edge of its distribution. Although geryonids are not obviously aggressive in captivity, field observations of crabs approaching traps do show agonistic interactions with threat displays typical of other brachyurans (Lindberg, pers. comm.). Competition for mates is not known, but prolonged mating may serve to prevent multiple males from copulating with a female.

A variety of commensal species occur on geryonids, including stalked barnacles (Poecilasma spp.) and a polychaete Dorveillia geronicola on C. fenneri and C. quinquedens. Although the density and size of barnacles fouling a crab's carapace may be indicators of time since molting, too little is known about the biology of the barnacles to calibrate their rates of settlement and growth. Chaceon quinquedens and C. fenneri also have a high frequency of chitinolytic bacteria, which cause dark lesions on their carapaces. The frequency of lesions may also be an indicator of time since molting, but little is known about the time course of their development nor of their potential pathology.

EDITED GROUP DISCUSSION TRANSCRIPTS

W. LINDBERG: We would like to hear comments about what you heard yesterday and, based on your experience, what you think the particular needs of the fishery are. Dick, do you want to lead off?

D. NIELSON: I'm Dick Nielson, commercial fisherman in Fort Lauderdale, Florida. First of all, I'd like to thank the people who set up this workshop. I think it's very interesting to me as a commercial fisherman, and I'm very proud to be here. You have done a tremendous job bringing these people from all over the world to this workshop. I particularly love workshops, more so because every time we go before regulatory powers here in the State of Florida we normally have about three minutes to speak, and I've been given a lot more time than that today and I appreciate that, believe me.

Commercial fishermen here in Florida are certainly under a lot of pressure. I wrote down quite a bit of information here, but I've got it titled "Golden Crab Trapping" and it really should be "Last Frontier of Commercial Fishing in Florida." I look at the deep-water golden crab as a last frontier, and I'm very interested in harvesting it commercially.

It all started about three years ago. Howard Rau, a commercial fisherman who traps for lobster and fish, moved out to deeper waters off Fort Lauderdale in search of fish. In 700 feet of water he began to catch golden crab in his fish traps. Howard Rau was the first fisherman to land golden crab in the Fort Lauderdale area. When I received news that we had golden crab off our east coast, and tasted some crab from Howard which was excellent, I decided to design and build a trap that would catch them more efficiently. This was done through research and trap design literature from Alaska, Canada and the University of Rhode Island.

The trap had three-eighth inch rebar frame and five-inch nylon webbing mesh on the sides and top with a one and a half by one and a half plastic coated wire on the bottom. The trap had a double funnel entrance five inches high, 24 inches wide. The trap size is four feet by six feet by 30 inches high. Five traps 900 feet apart make up a trawl. Because of the Gulf Stream conditions, traps were retrieved by grappling.

A five-inch escape ring was installed at a later date to release females and smaller males on the bottom. Research on golden crab reproduction and spawning was done aboard my vessel. I highly recommend a working relationship between fishermen and biologists. When the time comes to regulate the golden crab, I want to help determine those regulations.

Three of us fishermen at this meeting have a proposal of regulations that we would like to see in place on the golden crab before we even really get into harvesting this crab on a larger scale. One of the first proposals would be an escape ring sized to release females and small males. I would like the scientists to tell us the most appropriate size. Secondly, we recommend no harvest of female crabs. We have never harvested female crabs. The female is a smaller crab, about half the size of the adult male, and we don't catch that many of them. We think it's much better just to leave that female crab on the bottom and help to preserve this resource. The third proposal would be a carapace measure for the male crab that would translate to about a pound and a quarter male crab. We would like to release anything below a pound and a quarter, also targeted by the escape ring. Once again, I leave the width of that carapace measure to be determined from scientific research that has been done. We can get together with you people and come up with some figures on that.

I certainly have enjoyed this two day workshop. It has been a pleasure being here and I certainly encourage more research. Any time the commercial fishermen of Fort Lauderdale can help in providing a vehicle for this research, we are more than happy to accommodate you. Thank you very much.

W. LINDBERG: Thank you, Richard.

D. ARMSTRONG: What is the approximate size, in inches, of an animal that weighs one and a quarter pounds?

R. ERDMAN: About 125 to 130 millimeters.

G. HINSCH: If you look at the size range at which they seem to be reproductively mature, the smaller sizes for males coincide with the upper size classes of the females. About 130 millimeters and larger are mature males while 130 mm to about 85 mm are mature females. So if you exclude the lower size classes of mature males you would automatically exclude females.

D. ARMSTRONG: This fishery has been under way for three years in Fort Lauderdale?

D. NIELSEN: Yes, but in a very dormant state. We primarily earn our living with fish traps and lobster here. The vessels we have are too small for large-scale crabbing. Howard Rau already has a larger vessel and is gearing up for the golden crab, as well as fish trapping and lobster fishing. I am working on a new vessel now. It has been a long slow process gearing up for these fisheries. We have done the ground work, we have used the technique of grappling these traps and catching the crabs, and we have that behind us. We haven't really supplied crabs to market consistently, and the market looks good to me. We've shipped crabs all over the world; we've shipped crabs all over the country and it's been widely accepted, only we couldn't meet the demand. We have been pretty well stable and now that we're about to move out and start greater harvesting, we want to go to the federal councils and get some regulations in place before this industry takes off.

D. ARMSTRONG: Presently are there any state regulations at all?

D. NIELSON: Not to my knowledge. I don't know of any.

D. ARMSTRONG: Will the State automatically come in immediately or at some point when they sense the industry is expanding?

D. NIELSEN: When you fish federal waters the State of Florida has no jurisdiction. We work very closely with the federal councils. We are regulated with fish traps and lobster gear in federal waters, and we have a good relationship with the federal councils. I don't see any problem with going before them as fishermen and proposing these regulations, to get them in place so we can protect this resource and have it for a good many years down the road.

R. ERDMAN: The only thing that the State does presently is to code the species as part of the State's statistical analysis. The State presently records only gross pounds landed.

N. BLAKE: The State of Florida has been reluctant and will continue to be reluctant to either do any research or to participate in any regulations that involve a fishery in federal waters even through the catch from that area is probably totally landed in state waters. They just will not participate in any of the shell fisheries that involve federal waters.

D. ARMSTRONG: And that simply means beyond three mile limits?

N. BLAKE: Well, no, it varies (nine miles in the Gulf).

D. ARMSTRONG: It's surprising in a sense because most landings of dungeness crabs, for instance, are beyond three mile limits but states have jurisdiction. In fact, the federal government has abdicated authority in those instances and only retains it in partnership with, say, a state like Alaska in the case of Snow crab and King crab fisheries. It surprises me the State could never come to have their specific regulations and standards and enforce them.

F. LAWLER: This fishery was started after the Magnuson Act went into effect. The fisheries on the west coast were going long before that. I think that's one of the reasons why the western states retain jurisdiction and Florida doesn't in this particular fishery.

D. ARMSTRONG: Also in some cases with relatively little fisheries value, the federal government cannot afford commitment of funds to persistent monitoring and management of them, so it falls to the states to do so.

H. RAU: I think it's safe to say that we would oppose the golden crab being put under the jurisdiction of the state of Florida.

G. ULRICH: If you fish an area for a while do you notice a decline in the catch?

D. NIELSEN: We were very limited by the size of the vessel, 36 foot, and the hydraulics. The depth of the water limited us to working a certain area and we stayed in that area at that same depth. We yielded about

100 pounds per trap per week for two years. We weren't able to expand out deeper or move around like we normally would because of the vessel, so I can't give you a real answer to that question.

R. NIELSON: I wanted to add just a couple of things. To achieve that 100 pound average for over a year and a half, we were fishing from approximately 118 fathom to 125 fathom in the same basic area. There has been some talk about how much pressure the resource can stand, and either those crabs were six feet deep when we started or they were being drawn from a wider area than originally thought. These crabs could be moving miles to get to these traps because it's amazing the amount of crabs we took out of this one area. We would still be doing that today except another fisherman came and set more traps in the area right outside of where we were fishing, and since then I have moved to a different area. The catch has not been up to a 100 pound average, but there are days that we average 50, 60 pounds of crab which is acceptable to us.

Let's talk a little bit about marketing. When we first started marketing this crab we ran into all kinds of problems. Originally, we sold the crab whole. People took it home and boiled it for an hour and a half trying to get it to turn red, then would come back and complain. We got into the retail market where we sold fish and crabs. We talked with the owner to basically inform the people and had some brochures made up that explained how to cook the crab. We found that even when people cooked golden crab for 18 to 20 minutes and then pulled the carapace off, they had a mess on the top of their table and that turned people off. So we decided as a marketing gimmick to clean them free which would help the retail markets. When people buy these crabs in a retail market they pay for the whole crab, and the retail market splits it and cleans it so the people take home only what they eat. It's much easier for them, no muss no fuss.

Once people try this, they call the fish market every day. We can't even catch enough crabs to keep one retail market steadily in crabs. I brought in 500 pounds of crabs on Wednesday and they are probably gone this afternoon.

I think down the road that you're going to find its the live market that is going to last. We've had large boats from Alaska and Massachusetts come down and try to process and freeze the crabs on the boat, and they have all gone out of business. I think you'll see the only market that's going to last is for live crab. You can pack these crabs in styrofoam boxes, put a couple of ice packs on the bottom and couple on top, and ship them to Massachusetts, or to Spain. The crabs will get there with approximately a ten percent mortality rate, which is pretty decent. A lot of people won't eat a blue crab if it's dead. When a golden crab is dead you can butcher it and cook it, and it's perfectly fine. As for the shelf life, once a cluster is cooked, you can keep that crab in your refrigerator for five or six days and it's still perfectly good. It holds the flavor and doesn't spoil. You have to cook the cluster. If you don't cook the cluster, black spot occurs in a matter of hours, so once a crab is cleaned it has to be cooked.

One of the things I'm interested in, and that would interest you people, are the small crabs. From the reports we had yesterday no one knows where the juvenile golden crabs are. I would like to find that out. Just where do they go, are they way down deep and then migrate in shore as they get sexually mature?

I would like to say once again that if you are down in the Fort Lauderdale area and you would like to go out and see how we fish for crab, you are more than welcome to come out for a day. If you are planning studies, our boat is always open to anyone who wants to do the work to help the resource. I thank you for inviting us.

D. ARMSTRONG: I'm curious, what is the crab worth per pound either off the vessel or retail?

R. NIELSON: We get a dollar a pound off the boat, retail is anywhere from $1.49 to $1.69 a pound. We started out trying to get $1.50 off the boat, and they were selling it for $3.59 a pound retail. We had to cut way back. We were down to 75 cents, and the retail markets were selling them for 99 cents just to get it established. Once we got it established we raised the price up a little bit so we could make a decent buck at it.

A. HINES: That's for whole crabs?

R. NIELSON: Yes, that's the whole crab.

W. BLAKE: You've got to remember they are fishing some six to ten miles offshore, you couldn't sell it on the west coast of Florida at a dollar a pound because the fishery is 100 to 150 miles offshore and you need a much bigger boat. Your investment would be much greater almost any place besides the Fort Lauderdale vicinity.

R. NIELSON: We have it easy in some respects, by fishing only five to ten miles off the coast. But it's not the easiest thing in the world to fish in a two to four knot current, especially using the grapple to hook the traps.

R. MILLER: How large an area did you fish over the two years before you moved your gear, how many square miles of bottom?

R. NIELSON: I would say approximately six square miles.

R. MILLER: How many pounds did you take out of that area?

R. NIELSEN: I don't have an exact figure, but roughly an average of a thousand pounds per week for over a year and a half. Seventy-five thousand pounds would be a rough figure.

D. ARMSTRONG: Have you lost gear using the method of grappling?

R. NIELSON: No. When we first started we would go out there and grapple for six hours and not even touch a trap. Once you get used to it and get the technique down, you let the current work with you instead of against you. I've lost one trap to the bottom in three years.

D. ARMSTRONG: Do you have any feeling whether the traps would continue to fish through extended periods of time without bait, that is just by virtue of habitat itself?

R. NIELSON: We have stainless steel gates that hang down to allow the crab in but are not supposed to allow the crab out. Once the bait goes, these crabs will find their way out of the trap. Similar to the fish traps, we use what's called a wire tie which is a small diameter wire that construction companies use to tie rebar together. We use it on the golden crab traps in case the traps are lost, so eventually the door will open.

G. HINSCH: Do you get any of the giant isopods when you fish for golden crabs?

R. NIELSEN: No.

G. HINSCH: That's a by-catch in the Gulf of Mexico fishery.

R. NIELSON: I've seen them from the Keys, but I've never caught one. One fisherman in the area has caught one.

G. HINSCH: They are quite common out here.

R. NIELSON: We don't see them, probably because we're not fishing deep enough. I imagine if we get out farther we'll run into them.

F. LAWLOR: What other kinds of by-catch do you get?

R. NIELSON: Very little, we get a Cancer crab once in a while. On a big day you might have 20 pounds. There is a spider crab, Rochinia, that seems to be more on the upper depth limits where we fish. If the gear is moved to the inside limit of the golden crabs you'll get five to six of them in each trap. I caught maybe ten fish in three years, blackbellied rose fish and a Snowy grouper. Howard Rau caught a Spiny dog fish, another guy caught a Goose fish, and we caught one American lobster.

G. HINSCH: Did you ever find any shovel-nose lobsters?

R. NIELSON: No. We do catch them shallower in our fish traps, but we don't catch any out there.

W. LINDBERG: Sean or Howard, do you have any words of wisdom you care to pass along to us?

S. INGHAM: My name is Sean Ingham. I'm a commercial fisherman from Bermuda, and I would like to thank all of those who have been instrumental in inviting me to this workshop. I have learned quite a bit and it's generated quite of bit of food for thought regarding the future in Bermuda. I'm going to go back with this information, sit down with the authorities and see if we can come up with some answers and try to develop a fishery for golden crab in Bermuda.

At the moment I'm the only person working it in a very small way with just a few pots. I had to go south to Belize to set up a fishing operation, and while there we attempted to find golden crab but didn't. Instead we got a lot of Bathynomus isopods. We got our fishing operation going there and came back to Bermuda where I've only been back into fishing for about a year. This year I'm optimistic. I'm getting back into it, and we're in the infancy stage. No real markets are established in Bermuda, so I have to both catch and develop markets. Only a few restaurants use golden crab.

When we started back in 1984 with golden crab; we sold the crab live at $2.50 a pound, and the restaurants were able to make money. I think now that we can still maintain those prices even with inflation. As I said, we have to do everything ourselves right from square one. We have had promises from the Bermuda government to help us. Any questions?

N. BLAKE: What kind of catch rates do you experience?

S. INGHAM: Well, fishermen loathe change, particularly in Bermuda. They did not want to venture into new types of traps which you are familiar with, even with the documentation I got from Ray Manning and Warren Rathjen. We needed a trap that could be utilized both for fish and crabs, depending on the time of year, the circumstances, and markets. I was working an eight foot by eight foot, four-foot-six high trap, which was set around July 1st in 1984. We went back on July 4th, and we didn't know what we were going to catch, since none of the authorities could tell us what was out there. They told me I was wasting my time, there was nothing out there, and to forget about it. So these crabs came up on July 4th and jokingly we called it the Independence crab, because it was going to make all the fishermen independent.

Later on as we moved these traps into the areas between the banks and Bermuda's edge where the strong currents were, we had one trap that came up virtually packed, and we couldn't get it aboard the boat. Eventually, it just gradually broke up against the side of the boat. So then we started fishing smaller traps that we could manage better, and we found as we went down in size, the trap caught less. But we were averaging 30 pounds a trap, sometimes less, sometimes more. With smaller traps the crabs either got out or we didn't have much success. The shallowest depth we found the crab was in 420 fathoms, nothing shallower than that. We have tried up and down the slope and haven't found any.

E. WENNER: Have you found the sex ratios to be roughly equivalent off Bermuda? I know that Brian Luckhurst reported that, and I was wondering from your experiences whether you found a fairly equal number of males and females?

S. INGHAM: Most of that information Brian Luckhurst has. I have had enough to try and catch it and market it. We used to chill the catch down to about 26, 27 degrees Fahrenheit, and this narcotized the crabs, and stopped them from attacking each other. When we got in, that catch was weighed, and Loran fixes were available for Brian's information. He would have all that information.

D. NIELSON: What depth of water were you fishing?

S. INGHAM: 420 fathoms. We found the species of crab at that depth was the biggest. As we went deeper the crabs got smaller, and then a smaller species started. We went out as far as 1,900 fathoms. This year we're intending to go down to 2,800 fathoms relatively close to Bermuda on a one shot deal, because I'm now in the financial position to spend all my time researching. I was relatively close to shore working in a mile of water.

D. NIELSON: What size are these crabs, the largest male, four pounds, three pounds, can you give me a per crab weight?

S. INGHAM: We caught some very big crabs in the five to six pound range, and on one crab the carapace was about 20 inches across. Mind you, the funnels in the traps are large. I've seen the Nielson trap, and your funnels are not that big. I would say if you tried bigger funnels in a larger trap you may find a larger crab. With what you've done now, you're limited in the size crab you can catch, and that's not necessarily the biggest. The biggest one was weighed by Luckhurst at 16 pounds one ounce.

R. WALLER: Are we dealing with the same crab here?

S. INGHAM: There has been very little help from the government to determine that.

F. LAWLOR: Were you taking both males and females?

S. INGHAM: That's true. At the present moment we are still taking both sexes. No laws govern the crab in Bermuda. Similar to the FDA laws that you have in the United States, we will follow your example. Whatever laws you enact up here, we'll probably follow suit down there.

When the crabs came up, both the scientists and fishermen looked on it as a waste of time to throw the females and smaller crabs back because they were going to die. We didn't realize what a strong constitution these crabs have. We have found that out from the seminar here. Where machinery and refrigeration has failed, crabs have been held up to 50, 60 degrees and live. I think they have a chance if we can work out what size crab we're going to release. The mesh size we were working with was two-inch by two-inch mesh.

F. LAWLOR: Is that the size you use on the fish traps?

S. INGHAM: Same size on the fish traps. We are a heavily regulated fishing industry in Bermuda. Back four or five years ago, I had 100 legal traps. Prior to that it was 400, and they have cut me from 100 back to 50, and from 50 I've been cut back now to 34. This year we're being cut back to 26.

I have tried to find an alternative way of fishing in Bermuda for the fishermen, and have tried to get away from more traditional types of fishing because of complaints about overfishing, the targeting of small herbivores for filet, and the limited space and platform that we have to work on. I'm trying to find an alternative that the fishermen can get into and continue, but we need to regulate that right from the beginning rather than at the end and try to bring it back, which always has been a big problem.

R. MILLER: Conventional wisdom is that animals that deep are probably quite old and quite slow growing, so your fishing operation could be viewed as a mining operation rather than a sustained yield. Some other people have more experience with these deep water habitats, but I think that would be a safe generalization. You'll fish an area out once and the next time it will be your children who will fish it again. We won't have a sustained fishery at great depths for any commercial species.

N. BLAKE: It hasn't been brought up yet, but if we're talking management, sometime along the line in this fishery we should be talking limited entry, whether it be in Bermuda, in the States, or wherever. I don't know how the Nielson's feel about that but if 500 people see a resource out there, especially in a deep water species where it could be fished out quickly, limited entry may be the only answer.

S. INGHAM: As for limited entry, in Bermuda the fishermen have worked single traps. We attempted to use traps on strings and it didn't work out too well. We set traps about 500 feet apart but they tended to get snared up in the rocks. Now we have the knowledge, we've seen enough films and fishermen working.

Just a point of interest, doors on our traps, as part of the law in Bermuda, are tied with biodegradable rope by law. We also found that a conventional fish trap that's set in five or six fathoms, will last approximately three years. You go out to 30 fathoms, you get about two years from a trap. You take that trap down off the edge and go out for crab and you get about three months because the wire starts to erode very quickly, either from electrolysis or what, I don't know. The sisal rope in shallower waters is discolored after about six weeks. In 500 fathoms, that size of rope looks perfect six weeks later, but two weeks later that rope is perfect to look at, looks brand new, but falls apart. It's very interesting and I don't know why it happens.

We were catching most of the crab up into the north and northwest, and the bait in the trap was in excellent condition sometimes a week after. On the southern side of Bermuda, we found that the bait after just one day looked like it had been cooked. I thought it was being attacked by some type of bacteria but some scientists suggested it could have been hot vents.

W. LINDBERG: Why don't we shift gears and turn the floor over to our rapporteurs to try to integrate the biology from yesterday with some of the fisheries comments from this morning.

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R. SMITH: For _Chaceon maritae_, I would argue that it doesn't have a terminal molt. I propose that molt plus one other, in other words two mature molts. I think you know there are several reasons for that. For starters I have kept mature animals in tanks, and they have molted to soft shell, I am quite convinced that they are not terminal molters. Then related to the up and down movement pattern, I've done a lot of tagging, and I've got to look at it from a seasonal point of view. It tends to suggest a seasonal movement up and down, but by size. In other words, as soon as they got a little bit bigger they tended to repeat the tag returns from a shallower depth interval; as they were getting larger they moved up shelf.

A. HINES: Would that be just by default? If little ones are only found deeper, as they grow they disperse from that zone, and then you would tend to get them at shallower depths, or do you think it's really a directional movement?

R. SMITH: I'm not quite sure, but what I would say is that generally the slope is of a distance that they could easily move five, ten miles up slope and get to whatever depth they would like, so it seems that they could easily move that distance if they wanted to. It seems that shallow is more suitable to them.

R. WALLER: I think they would be moving up slope in reaction to food. More food would be up slope than down slope, and the larger animals that require more to eat would move to an area where they might feed better.

R. SMITH: Could be.

G. HINSCH: Roy, you have two mature stages for females?

R. SMITH: Yes.

G. HINSCH: You don't think that the second one molts again, and that isn't a terminal molt in that instance? You think they molt to that second mature stage and then just die?

R. SMITH: The period between these first two mature stages is so extended, probably about four years or so. Maybe they never get the chance to molt again because the third mature stage might be so extended that they never even reach it, might possibly get taken by predators before then.

Another thing that also makes me think that they have two mature stages is that portunids have a series of two mature stages. As Ray Manning was saying, the Geryonids are so closely related to the portunids, that they possibly have the same pattern.

G. HINSCH: But if you assume that any animal within a single instar would vary, they would not all be the same. Wouldn't you expect to see some sort of a double bell curve in the sizes?

R. SMITH: No, you don't.

G. HINSCH: With _Chaceon_ several people have shown that the maximum size of females is approximately 13 and a half centimeters but they hardly ever find them beyond that.

R. ERDMAN: We have recorded ovigerous females as wide as 156 millimeters.

G. HINSCH: Very few of them.

R. ERDMAN: But I have never seen any bi-modal suggestion in my data.

G. HINSCH: That's what I'm saying. If you were to have two different stages wouldn't you have a bi-modal situation, with one instar having the largest frequency at one point and then the next instar having again a large number of individuals?

R. SMITH: I don't think you would see that because you took data at the end of it's life history and by that stage there are all sorts of different growth patterns.

G. HINSCH: But in Chaceon, females release their eggs, their embryos, and internally they have fully developed ovaries. If you consider the energy necessary for ovarian development it would seem very unlikely that large numbers of females are going to undergo vitellogenesis and release their larvae, with vitellogenesis occurring at the same time as larval development and then not continue on to have another brood from those eggs which they contain within them.

W. VAN HEUKELEM: I don't think you would see a bi-modal distribution as Tuck Hines was talking about, possibly because of large growth increments. The only juvenile we had that was any size was 82 centimeters and it molted to 91. That's only an eleven percent increase at the molt for that size. If you have much variation at all it's going to wipe out a bi-modal distribution. We found with our juveniles that they started out with about a 43 percent increase of stage one to stage two, and by the time they were going from crab six to crab seven it was down to about 14 percent. It looks like as size increases the increment percentage decreases.

A. HINES: You could have a declining molt increment with increasing size so that the juveniles would have a fairly high molt increment and the larger adults would have decreasing molt increments.

W. VAN HEUKELEM: That's what our data show.

A. HINES: That's common in xanthid and grapsid species.

P. HAEFNER: To follow up on one of the things that Tuck Hines was saying about taking careful measurements and observations, I haven't heard anything expressed here about observations on parasites of these crabs. I don't know the growth rate, for example of the octolasmid barnacle, but if you see a crab that's loaded with large octolasmid barnacles, you get some sense as to how long ago it has been since that individual has molted. You should see the same thing with parasites in the gill chambers. It takes a little more effort and a little bit more time to look for these things, but I think it's worthwhile in the long run.

A. HINES: The most obvious commensal with these species are the stalked barnacles that occur on the carapace.

R. ERDMAN: That not Octolasmis, it's a poecilasmid. There isn't enough known about the biology of that species to know how fast it's growing.

P. HAEFNER: We need to get some commensal biologists involved here too.

G. HINSCH: With one specimen there was a large polychaete worm about six inches long. I don't have the name with me but I can get it. This was found in the gill chambers of the red crab, we never found it in Chaceon fenneri, but they were quite common.

A. HINES: I think that you can get some information about that, but it's more qualitative information, and I would be cautious because it's difficult to make strong inferences from that. It helps support more direct information from the crabs and their molt stage, so I think it's worthwhile.

R. ERDMAN: Regarding both commensals that we just discussed, the barnacles we've collected from both Chaceon fenneri and quinquedens have been sent to Dr. Williams in Wales, thanks to Tuck. That group appears to be a taxonomic nightmare. And regarding the gill worms, we have collected extensive numbers of polychaetes from Chaceon fenneri from both the east coast and the west coast. They seemed to be fairly common. Tom Perkins from Florida DNR has identified them.

E. WENNER: We also found this particular polychaete in Chaceon fenneri in our collections.

D. ARMSTRONG: I have a question both for the fishermen and probably Bob Elner and it has to do with your desire to predict consequences of certain actions, and this relative to the ecological role of the animal in the community. To date the fishery has been very gentle, in fact not nearly big enough to have some sort of impact, probably on the standing stock of big animals at the top of the size range. It is in fact the mining point of view that you suggested, Bob Miller, which is to say it's right now like some of the virgin Snow crab populations, old animals tending to inhibit growth of younger age classes. Once removed, the big animals will obviously be a rare commodity but also will evoke certain kinds of reactions in the population as a whole. A lot more may grow, but to smaller sizes. How does the Canadian government approach exploitation of that kind of a fishery which is predicted to be slow in recovering, and how would fishermen want to handle it in this particular case? We heard the suggestion of very limited entry as one type of regulation, but I guess you might need to be prepared for the possibility that your fishery comes to an end over a fairly short time and takes a long time to recover.

S. INGHAM: I would like to say that if any study is going to be done in Chaceon, Bermuda would be an ideal place to do it because of the quick incline of the slope. At 420 fathom the larger species disappeared and at about 500 fathom another species took over. You are in close proximity to land and we have a day-time fishery, no one really fishes at night.

A. HINES: What species is that?

S. INGHAM: Chaceon Fenneri.

A. HINES: Do you see C. quinquedens?

S. INGHAM: Yes. There are several species there but they seem to be governed by depth. The largest of those species are at the shallower depths and the smaller ones deeper. You're within a very short distance of these depths, whereas along the continental United States one has to go many miles before depth changes. Also the funnels of the traps may be a very good device to protect the larger species. By restricting the size of the funnel, you leave the larger species for reproduction. I don't know if anyone has got any comments on that.

A. HINES: So you're suggesting then that there be both an upper and a lower size limit on the catch.

S. INGHAM: Once we know the maximum size of the species that is being targeted, I think something could be done along those lines similar to what has occurred in Maine with lobsters. I would like to hear more comments on that because I don't know what effect that will have.

P. HAEFNER: One thing to add about the American lobster. We have the classic case along the east coast, off the coast of Virginia when they discovered an offshore lobster population there. The very large 15, 20 pound lobsters were fished out very quickly down to five and three pounds. I lost track of the status of that but perhaps either Bob Miller or Bob Elner can relate to that in New England and off Canada. You can very quickly deplete the big individuals, and if Chaceon is indeed a very slow growing species, with intensive fishing efforts you probably would see a reduction of that upper mode. Of course, I don't know if Roy Smith has experienced that either.

R. ELNER: I think it all points to the real importance of monitoring this fishery as it takes off. You are looking at the number of soft shell crabs in the fishery every year and looking for other signs of recruitment. To get back to Dave Armstrong's question, until we know that recruitment we must proceed cautiously. If it is a mining operation, there are a number of management strategies you can use. You can use measures whereby you only fish that species every ten years or every five years. Alternatively you enclose areas and fish one area for two years and then close it for five years. Or you could make sure your exploitation rate is very low so you can let very few fishermen in the fishery. There are a number of management strategies, but it all depends on the response of the stock harvested in terms of recruitment.

W. LINDBERG: Getting back to one of the comments that Dave Armstrong made about the Alaskan fisheries, that recruitment events may be occasional although reproduction may be regular or annual. Successful recruitment events don't necessarily follow from that. In a comparative sense being long lived, with late maturity and a tremendous investment in reproductive effort compared to other crabs, could it be that we are having trouble finding juvenile size classes because this is only an occasional event? If an animal is living for 30 years and reproducing annually over a good portion of that time, could it be that successful recruitment from any given individuals's brood is only happening a small percentage of that time?

A. HINES: That's a distinct possibility. I think that we really don't know enough to answer that question for sure about any of the species of Chaceon, but we have similar cases in other species of crabs to show that's a possibility. The Snow crab situation and also King crab that Dave Armstrong mentioned seemed to indicate that's a possibility. In the case of Snow crab, changes in size structure of the population are concomitant with fishing pressure, and seems to result in differences in the mating biology and relative contribution of different sizes to the reproductive output and reproductive success of the population. That can vary geographically among fishing sites through the range of the species. It is something to be concerned with.

That kind of information is needed on Chaceon, but it's not something you can answer quickly; there is no simple test for it.

R. NIELSON: I fished New England lobsters in Massachusetts for about 20 years. The question here is the large animals and what's going to happen to them. It's been my experience that with any new resource in the marine field, you're working on the large adults and those are taken right off the top. Then, it comes down to a level where you get an annual yield, so I really don't see a problem with that. The larger animals are taken right off the top of the resource. That occurred on the offshore lobster fisheries up in New England. The inshore lobster fisheries which I participated in ended up so that we were taking a certain size lobster down to a level, and we were throwing back the smaller ones that were next year's stock. We were then harvesting every year, and it stayed at that level for 20 years. I've been out of that fishery for over 18 years now and it's still at that level, so I don't really see a problem of taking heavy, larger animals off the top of a resource.

Secondly, the state of Maine is the only state in New England that has the large carapace measurement to protect the larger male and female lobster. I don't see any purpose of it. I don't see where it's helped them, but it probably hasn't hurt them.

A. HINES: The real concern in most fisheries management strategies is to be sure that the size restrictions exceed the size and age at first reproduction, and that it not be just physiological reproduction but that they're functionally able to reproduce. For example, in the Dungeness crab fishery and in most crabs, males must be larger than females in order to mate. So while a small male may be physiologically mature and capable of reproducing, in fact, they are not contributing very much to reproductive output of the population. You must have that minimum size females, for example, related to the functional reproductive biology, not just the age at which they become mature. We need to know a little bit more about that in Chaceon. We don't know enough yet. I have seen males in copulating pairs and the few data we have show males are quite a bit bigger than the females, not just equal to the largest size of the females.

D. ARMSTRONG: I would tend to agree that an upper size limit doesn't seem wise or necessary in this case. And the trick is whether or not there will be sufficient size differential between your economically viable minimum and that of a crab which is also bred. The fact that so many people report low percent ovigery, but at times that it's high, is somewhat troublesome. In most other crab fisheries that are surveyed, those females of theoretical mature size are almost always 100 percent ovigerous in season. Yet for these animals a lot of times tiny fractions are carrying eggs. It may just be a quirk of continuous reproduction at depth, as has been suggested, but it also could be evidence that they don't all reproduce annually.

I was going to ask Bob Whitlatch, that if these animals are severely food limited and, considering the size frequencies for males, the fishery crops the population to 140 millimeters, and that provokes some sort of numerical response in terms of more smaller crabs, can you anticipate any effect that might have on the overall community?

R. WHITLATCH: To my knowledge I can think of no good example. A lot of times you don't see immediate responses to predict this in terms of typical fisheries.

D. ARMSTRONG: They have got to be either worse off, better off, or no different in terms of the overall food supply for more smaller animals if they have this cap of larger animals removed.

R. WHITLATCH: One would predict that there should be a response of the food resource availability as the predators decrease, although there are other factors involved. Fishes might replace the crabs and have a similar sort of cropping behavior. We don't know a lot about the feeding ecologies of these deep water organisms. By the way, an unpublished Ph.D thesis by Jim Farlow of Yale University deals with gut contents of trawl surveys. Generally most of these large forms are really opportunistic feeders and it's felt that they crop their food resources very nonselectively. So the presumption here is that if you decrease one species you might increase another species.

W. VAN MEURELEN: I would just like to reiterate what's been said several times in terms of learning more about the importance of juveniles, where they are and what their movements are. I think we have pretty extensive trawl surveys on Chaceon and have only gotten very few juveniles and those were at great depths compared to the adult population. I was interested in Roy's comment yesterday, that they found a lot in fish guts so they knew that they were in shallower water; it that right?

R. SMITH: That's right.

W. VAN HEUKELEM: So this dissertation might be very interesting to look at.

R. WHITLATCH: I would also reiterate several comments people have made about the importance of integrating information that is required to understand the resource for fisheries and the importance of the genus in the slope environment. We have a somewhat unique situation here in terms of research initiatives and funding agencies for this sort of research. Many of the states are not going to be interested in supporting research activities that occur in federal waters. Research could be motivated by two issues, the basic biology of the organism and the role it plays in upper slope communities. At the same time, gain the appropriate information that people have pointed out concerning the crab's potential as a fishery resource.

A. HINES: I would like to second that. From Ray Manning's discussion of the increasingly apparent diversity and world wide distribution of this group, what we learn about the biology of Chaceon species in the U.S. and off the African coast is likely to have world-wide implications for that depth zone in the ocean. From a basic research point of view as well as fisheries management, there are important issues. We're learning a lot about that depth zone, and we're bringing new technological advances to bear on those research issues that we haven't been able to approach in the past. In my view, it's somewhat analogous to the rocky intertidal ecologist suddenly donning scuba gear and finding out there is a whole lot going on below the low tide mark. There is indeed a lot going on in the typical fishing zones that have been sampled in the past.

Secondly, there are other aspects of the biology from a community point of view, on trophic interactions, that we haven't raised here. We've talked a lot about this depth zone that seems to be consistent and distinct when two or more species of Chaceon overlap, and that there is a vertical segregation with C. quinquedens, for example, always found deeper than C. fenneri. Well, why is that, what maintains that? It is simply some intrinsic depth preference of temperature preference or are there biological interactions between fenneri and quinquedens that you might expect to observe that would be competitive, either exploitative or interference competition?

We haven't talked about competition among individuals. If food resources and access to mates are really important, that would suggest why this species has long distance sensory abilities, and also potentially could suggest a reason for the common occurrence of black scars on the crabs that might be due to aggressive interactions, or could be just due to crabs banging into things on the bottom. We see that both on C. fenneri and C. quinquedens and I suppose on other Chaceon species.

And finally, we raise the issue about what are some of the predators on these crabs. We talk about fish preying on the juveniles, but we don't know how common that is or how important that is to the fishery resources on that slope. It would be worthwhile, if you fishermen catch some fish in your traps or in your trawls, to look at the stomach contents of those fishes and determine whether they have little crabs in their stomachs.

W. LINDBERG: On the questions of species interactions, with our broad scale sampling in the Gulf, if it was species interaction setting an upper limit for red crabs, then you would expect an ecological release in the absence of C. fenneri. We don't see this in the northern Gulf where the bottom types are appropriate, with predominant by mud-silt bottom at shallower depths. There are no C. fenneri there. If species interaction set the range, then you would expect C. quinquedens to move up, and they don't.

R. WHITLATCH: In New England we don't have C. fenneri, but it's been suggested that Cancer irroratus is out competing Chaceon quinquedens in the shallower waters. So there may be another species, maybe not a Chaceon, that is fulfilling the role that C. fenneri is playing.

W. LINDBERG: If it was filling the role of C. fenneri you might expect it would be sampled in the same fashion as C. fenneri, and we didn't have that. The intermediate and shallowest depths in our sample weren't producing some replacement for C. fenneri. The C. quinquedens were simply not moving up, which suggests something else is limiting them.

C. TRIGG: We don't see aggressive behavior when we hold the species together in overcrowded conditions.

W. LINDBERG: There may be not be cannibalism, but with trap observations, we do see clear aggressive behavior as they first approach the trap. There are cheliped displays, there is contact interaction, there is a fleeing of the smaller individual, things that are characteristic of all the other crabs I've seen. If there are low frequencies of molting and a small proportion of the females are receptive at any given time, there could be some fairly intensive competition among the males for mates. Given that they are incopulo for such a long period of time, rather intensive sexual competition is suggested.

R. ERDMAN: To return to bathymetric distribution, we have completed oxygen consumption measurements over temperature ranges on Chaceon quinquedens and Chaceon fenneri. The experiments were this fall, and I haven't finished the analysis, but we did measure both species and both sexes over time in a respiration chamber. From visual observations, there seemed to be a slight sluggishness at warmer temperatures with C. quinquedens. They just don't do as well. They survive but are inactive and don't feed. Data that are published, whether from gray literature or not, suggests an upper temperature limit. Yet, the species has been recorded from temperatures as high as 12 degrees Celsius, but some of the gray literature reports that above nine or ten degrees the species begins to show potential physiological disturbances of physiological discomfort.

R. WALLER: Depth distribution is really interesting. Sean said he didn't collect C. fenneri at depths above 420 fathoms, and yet in the Gulf we get them at 200 fathoms which is our best sampling range.

R. ERDMAN: On the east coast when we first started to work with Dick Nielsen, we were fishing about 120 fathoms. We set traps in the Gulf at 120 fms and got one crab. On the east coast of Florida the Gulf Stream spills onto the shelf along the Fort Lauderdale area. It would be interesting to see what the temperature is like in the Bermuda area. Obviously finding out the physical conditions are very important.

R. NIELSON: When I was catching more crabs than I had markets for I decided to take a couple of trawls of traps and see how far in I could catch the golden crabs. At about 600 feet I only caught a few, and inside of 600 feet there weren't any. Beyond the hundred fathom curve, you didn't really get into crab around 118 fathoms. At that depth there were a few but not enough to be commercially viable.

R. MILLER: Two rather extensive comments. First, distribution and abundance is what seems important for both ecological and fisheries applications. As biologists we're not very experienced in giving density estimates of large deep water animals. I think the funding agencies should be patient with applications, that simply refine and develop measuring real density, and absolute density of these animals in deep water. It's not glamorous perhaps but it is necessary.

A. HINES: Certainly the videos on the submersibles are a very good way, but very expensive way to do that.

R. MILLER: Secondly, regarding a management plan, if I were to make one, initially I would do it exclusively from economic considerations. I would set a minimum size based on what you could sell. Don't waste it, only catch what you can sell, independent of considerations of reproductive size. I would expect that, at least now, there are a lot of refuges inaccessible to fishing either because of depth or because of low density of the prey animal. I think one could fish until you get down to a certain minimum. If the industry is uncomfortable with that, set a tentative quota, say three million pounds for southeast Florida. If it takes one year to get there or five years to get there it doesn't matter. When you get to two million pounds close the fishery for five years and open it again and start over. But it's going to be, I'm almost certain, a mining operation or very close to that. The American lobster is not, unfortunately, a good parallel because it's a shallow water, fast growing species and these animals are not, I'm sure. You're going to fish them once and leave them for maybe another generation of fishermen.

R. WHITLATCH: No one has said anything about black spot disease, is that a concern? In New England it's of great concern and it's been suggested that red crabs might be a good model to use to look at the incidence of black spot disease.

E. WENNER: What he is talking about is not melanosis but the presence of chitinolytic lesions. We found 99 percent of the individuals that we sampled had incidence of chitinolytic bacteria. In some cases it was very extensive. It is certainly of interest that in blue crab populations that is also beginning to show up in North Carolina. It's also extending to South Carolina and is being picked up in Chesapeake Bay now where it is being related to pollution. I think we definitely need to know more about why there is such a high incidence of chitinolytic bacteria in Chaceon fenneri and Chaceon quinquedens in the deep sea.

R. WHITLATCH: It's one more motivation for studying the animal. I'm thinking if we can't interest agencies that are interested in the organism or the fisheries resource we might interest agencies that might like to use it as a monitor for pollution on the upper slope. We can broaden our base here.

A. HINES: Any other comments?

D. ARMSTRONG: Just a point of interest, I'm always curious where people get their crustacean funding. You've been on a little bit of a roll in this part of the world, what do you anticipate the source and likelihood and level of funding will be? Is it all going to be federal government or will your Sea Grant and local states continue this for five years?

W. LINDBERG: Well, the prognosis isn't all that great. I would say we have been riding the wave of fisheries development in the southeast and now we have a handle on this. It doesn't have that appearance of being another King crab or Snow crab, although it can be a viable localized or regional fishery. Motivation from Sea Grant, National Marine Fisheries Service, and the fisheries development view has probably run its course.

D. ARMSTRONG: That gets back to Bob Whitlatch's comment of hooking the wagon to other ecological types of studies and agencies to fund it.

E. WENNER: I have that distinct impression too that we were able to acquire a fair amount of funding through the region. This type of research takes a lot of funding. Just from my own experience, I received funding from five different agencies, and put it all together into one package which required a great deal of effort. But it required a great deal of money to be able to do the work. What I'm sensing now is that with golden crab being the only topic of directed research efforts, I don't think we're going to be as successful in getting that funding. These species are going to have to be looked at in a more ecological or community role, as opposed to golden crab being the sole focus of the research.

W. LINDBERG: That's part of the agenda in bringing so many different people from different regions and different viewpoints together. We have the opportunity to forge interdisciplinary or multi-investigator approaches to the broader scale ecological questions; that's in all of our best interests, especially when viewed on the comparative basis that Ray Manning has given us, and considered in the broader context of other crustacean fisheries.

A. HULBERT: Certainly our research center is very interested in this problem. A large part of the reason for participating in this workshop is to get a multi-disciplinary group like this together. The center in the past, as Betty and Bill know, has been effective in providing the equipment and utilizing that as a seed along with other kinds of funding like Sea Grant and state agencies. Certainly from our point of view, the funding that we're looking at now, and the research agenda, is for big scale projects. The kinds of things that are fundable are Gulf of Mexico ecosystems versus South Atlantic ecosystems, and what functions are involved, and the integration of physical oceanography with larval recruitment processes. Those are very important things we can do. We have very good reason to reach out to marine geologists and hydrologists, oceanographers, in terms of funding. Put your interests in context of a bigger plan, a multi-interdisciplinary study, and use it as a seed to get together and go forward.

W. LINDBERG: That perhaps is the best wrap up to have. Something to go home with, a challenge to work with. I would like to thank all of you for taking the time out of your schedules to come here and enjoy the Florida sunshine. We formally stand adjourned.

SUMMARY OF RESEARCH NEEDS AND OPPORTUNITIES

Kelly et al. proposed a model for C. quinquedens larval transport in surface waters which was supported inferentially here by R. Smith for C. maritae and Lindberg et al. for C. fenneri. As noted by W. Van Heukelem, rapid larval development rates at warmer surface water temperatures should favor the restricted geographic distributions of geryonid species reported by R. Manning. Is vertical larval migration and surface water transport the rule among geryonid crabs? If so, what are the general implications for recruitment processes and life history strategies of these crabs and associated fauna.

Juvenile geryonid crabs rarely appear in samples, and then mostly from deeper collections. This pattern led previous authors to hypothesize that settlement occurs deep on the continental slope with subsequent up-slope migration during ontogeny. As noted by A. Hines, one alternative hypothesis is that settlement occurs across the slope followed by higher natural mortality of juveniles (e.g., from predation) at shallower depths. Another possibility, derived from comments by W. Van Heukelem concerning juvenile growth rates at different temperatures, is that crabs which settle into deeper zones are locked into juvenile size classes for ma--y more years and are, therefore, more likely to appear in samples, given low recruitment rates and markedly different growth rates across the bathymetric range of a species. What are the settlement patterns of geryonid crabs with respect to depth? What are the subsequent development and mortality rates, and how do they vary across depths?

Similarly, if larval transport by surface currents as proposed by Kelly et al., R. Smith, and Lindberg et al. is confirmed, to what extent should we expect settlement to be concentrated geographically or with respect to hydrographic features?

In general, growth rates (increments and molt frequencies) and age at first reproduction are poorly known for geryonid crabs. Accurate, detailed molt staging should be incorporated into future sampling regimes, while controlled laboratory experiments to test effects of ecological variables are particularly desirable.

A terminal molt with mating in the h -d condition was suggested by G. Hinsch based on histological analyses, but this was countered by R. Smith, R. Erdman et al., and H. Perry et al. with field data and direct observations of captive pairs. As noted by A. Hines, resolution of such questions is possible with careful attention to detail, e.g. the occurrence of limb buds on ovigerous or post-spawning females.

At the population level, C. fenneri exhibits an seasonal reproductive cycle, C. maritae year-round reproduction, and C. quinquedens a protracted seasonal to continuous reproduction perhaps dependent on geographic location. Why should some geryonid species or populations show circannual periodicity while others do not? Regardless of cyclic or acyclic reproduction, only a low percentage of females are ovigerous, or pre- or post-molt at any given time, suggesting that individual reproduction is not necessarily annual. R. Erdman and N. Blake hypothesized a biennual reproductive cycle for individual female C. fenneri, while A. Hines suggested reproduction on an annual cycle or longer contingent on adequate energy reserves. Comparative studies and experimentation are needed to resolve questions of this basic life history trait.

R. Elner et al. and H. Perry et al. reported that copulation and mate guarding lasted many weeks for C. quinquedens and C. fenneri, respectively. When combined with a potentially low incidence of receptive females, this indicates extreme levels of intrasexual competition among males for mating opportunities. Lindberg et al. inferred seasonal shifts in the bathymetric ranges of male and female C. fenneri, and that large males carried mated females downslope to strata with low population densities to avoid competing males and minimize disturbance during mating. Seasonal movements, encounter rates among potential mates and competitors, movement by mated pairs, and takeover attempts all need to be documented to test geryonid mating strategies.

Geryonid species apparently differ in habitat preferences, with consequences to overall ecological comparisons and linkages to physical processes. The red crabs C. maritae and C. quinquedens have been found exclusively on soft bottoms, while Lindberg et al. and Wenner et al. reported greatest densities of golden crab, C. fenneri, from hard bottom habitat. R. Manning noted differences in leg dactyl structure consistent with weight distribution on soft bottom versus climbing ability on hard bottom topography. R. Henry et al. found that C. quinquedens were slightly more tolerant to hypoxia than C. fenneri. Whitlatch et al. attributed substantial bioturbation of soft bottom to the activities of C. quinquedens. Basic ecological questions concerning physiological ecology, refuges and foraging habits, trophic dynamics and community relationships remain largely unanswered. Given the predominance of geryonid crabs on the upper continental slope, resolution of these questions should illuminate much about general slope ecology.

Related to foraging habits of these crabs, trapping efforts have been successful despite low population densities revealed through submersible transects. Geryonids apparently exhibit particularly keen chemosensory and orientational capabilities, and great motility. This and habitat relationships raise questions about home ranging versus nomadism among species, and the relative importance of bonanza food falls versus benthic predator-prey relationships. The practical consequences of such questions concern effective areas fished by traps and the resiliency of fishing grounds to persistent fishing pressure.

The questions above pertain mostly to life history strategies and fundamentals of geryonid ecology. In part, this reflects interests of the workshop organizers, many participants, and fisheries interests. Equally valid, however, are questions of basic physiology of deep-welling organisms, biogeography and systematics, or parasitology and symbiosis. Regardless of discipline, the recent systematic revisions within Geryonidae by R. Manning and Holthius reveal taxa ripe for comparative studies.

Industry needs for harvesting, processing and marketing information have been addressed with modest research not thoroughly covered in this workshop. Nevertheless, these areas, plus basic economic considerations, could and perhaps should be compiled with existing biological data into a draft fisheries management plan for Geryonid fisheries of the southeastern United States.

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Appendix M. In Situ Estimates of Density of Golden Crab, *Chaceon fenneri*, from Habitats on the Continental Slope, Southeastern U.S. (1990)

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units. Then, the estimator CT of the total catch is $CT = v \cdot B \cdot L \cdot \bar{C}$. c) The best estimate of the total catch can be obtained by adding the total catches per month, each one calculated multiplying C(t) by the total number of trips of the month v(t): $CT = \Sigma\, C(t) \cdot v(t)$.

To show the reliability of this method, some estimates of total catches are presented in Table 1 including, for demonstration purposes, large-scale fisheries in which total catch is known.

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IN SITU ESTIMATES OF DENSITY OF GOLDEN CRAB, *CHACEON FENNERI*, FROM HABITATS ON THE CONTINENTAL SLOPE, SOUTHEASTERN U.S.

E. L. Wenner and C. A. Barans

Abstract

Observations on density and habitat of golden crab, *Chaceon fenneri*, were made from a submersible along 85 transects in depths of 389–567 m approximately 122 km southeast of Charleston, South Carolina. Additional observations on habitat were made on 16 transects that crossed isobaths between 293–517 m. Seven habitat types were identified during dives: a flat foraminiferan ooze habitat (405–567 m); coral mounds (503–555 m); ripple habitat (320–539 m); dunes (389–472 m); black pebble habitat (446–564 m); low outcrop (466–512 m); and soft-bioturbated habitat (293–475 m). A total of 109 *C. fenneri* were sighted within the 583,480 m^2 of bottom surveyed. Density (mean no. $\cdot 1{,}000\ m^{-2}$) was significantly different among habitats, with highest values ($0.7 \cdot 1{,}000\ m^{-2}$) noted among low rock outcrops. Lowest densities were observed in the dune habitat ($<0.1 \cdot 1{,}000\ m^{-2}$), while densities for other habitats were similar ($0.15–0.22 \cdot 1{,}000\ m^{-2}$). The low density (1.9 indiv. $\cdot ha^{-1}$) of golden crab in the study area compared to estimates of red crab density (258–282 indiv. $\cdot ha^{-1}$) off southern New England suggests that golden crab stocks may be substantially lower than those of red crab. The golden crab population in small areas of 26–29 km^2 between 300–500 m off Charleston was estimated to be 5,000–6,000 adult crabs.

900–1500'

The golden crab, *Chaceon fenneri*, is an inhabitant of the continental slope at depths of 275–915 m in the Florida Straits, Gulf of Mexico, and off the eastern United States (Manning and Holthuis, 1984, 1989; Wenner et al., 1987) and has been reported at depths of 786–1,462 m near Bermuda (Luckhurst, 1986). Most of the information on this species to date has been gleaned from trap catches either through exploratory research (Otwell et al., 1984; Wenner et al., 1987) or commercial fishing efforts (Manning and Holthuis, 1984; Hinsch, 1988; Luckhurst, 1986).

Although these efforts have provided some information on the life history and distribution of the species, much remains to be learned about the relationship between habitat and abundance of *C. fenneri*. Information on sediment composition taken coincidentally with trapping activities indicated to Wenner et al. (1987) that abundance of golden crab was influenced by sediment type. Their catches were highest on substrates containing a mixture of silt-clay and foraminiferan shell. At depths >550 m, large coral mounds were encountered, and traps set at that depth were regularly lost or retrieved with no crabs. In contrast, the largest catches in the Gulf of Mexico were from cobble, rock outcroppings and vertical rock walls (W. Lindberg, University of Florida, 1987, pers. comm.). The purpose of this study is to provide information on habitat types and densities of golden crab from submersible observations in the South Atlantic Bight. Estimates of the densities of adult crabs and the areas of each habitat type were expanded to estimate population sizes for habitats.

Methods

In situ observations on density and habitat of golden crab were made during three dives of the Johnson Sea Link II in August 1986; 12 dives from 30 July–3 August 1987; and four dives in November 1988. An area of the upper continental slope between 31°50'N–32°05'N and 78°55'W–

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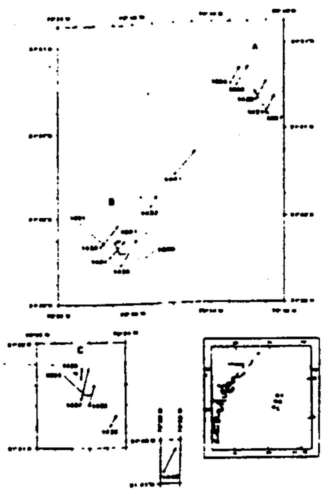


Figure 1. Location of submersible dives in the South Atlantic Bight. Lines depict submersible transects.

79°15'W, approximately 122 km southeast of Charleston, South Carolina, was divided into three equal and discrete sampling areas that encompassed locations where trapping took place in 1985–1986 (Fig. 1). Observations and crab counts were made along 85 transects in depths of 389–567 m during 1986 and 1987 (Table 1). Location of the first transect of most dives was randomly chosen in the areas shown in Figure 1, and subsequent transects on a particular dive were a continuation of or were parallel to the first. In 1988, habitats were quantified along 16 transects that crossed isobaths between 293–540 m (Fig. 1). The beginning position was selected to traverse transect paths of previous dives in 1986 and 1987. Data from 1988 transects were used only to describe habitat types and estimate their proportion across isobaths.

Prior to transects on 1986 and 1987 dives, the submersible remained stationary, with minimum light emission, for a 3–5 min acclimation period and determination of position by personnel on the R/V EDWIN LINK. Upon completing these procedures, the submersible proceeded along the transect in the direction of the current, and counts of *C. fenneri* were recorded. On the first five transects made in 1986, three 1-min stationary counts were made with full lighting immediately following the acclimation period and after each transect. Because the same crabs were counted for the three-point estimates after each transect, these counts were abandoned on later dives in order to maximize transect time. Survey transects were ~15 min in duration, except when there was a major change in habitat type. Distance traversed during transects ranged from 188–522 m, with three to seven transects completed per dive. Transects from the 1988 dives continued until a major change in habitat occurred, at which time the submersible's position was determined. Time, depth, bottom water temperature, current speed as measured by an externally mounted current meter, habitat characteristics, biological observations, and position of the submersible were recorded at the end of each transect for all dives. Sediment was collected by a grab sampler at the beginning and end of each transect and when bottom type markedly changed.

Videotape and 35-mm still photographs were used to document changes in habitat and topography. Observations were simultaneously recorded on audiotape and on videotape, and both were used to assess the number of individuals of golden crab encountered. Estimates of population density were determined for the area of each transect, which was defined as the product of the transect distance and the horizontal visibility, as estimated by a pilot experienced with previous measurements (Parker

Table 1. Summary of counts of golden crab and habitat types encountered on submersible transects (CM = coral mounds; BP = black pebbles; DU = dunes; FO = flat ooze; LO = low outcrop; RI = ripples; SB = soft-bioturbated)

Dive	Transect	Depth (m)	Total area (m²)	Individuals (No.)	Habitat
1855	01–05	413–414	30,521	5	SB
1856	06–11	472–475	36,874	7	SB
1857	12–18	521–555	65,179	16	BP, FO, CM
1430	01–06	517–558	33,950	4	FO, RI, CM
1431	07–11	536–567	33,098	1	FO, BP, CM
1432	12–15	405–408	25,929	2	FO
1433	16–21	443–452	45,228	7	FO
1434	22–26	497–521	40,408	11	FO
1435	27–32	481–512	35,484	16	LO, BP
1436	33–36	531–539	21,488	5	CM
1437	37–43	419–461	53,458	22	FO, RI
1438	44–46	389–411	18,543	1	DU
1439	49–54	503–534	47,095	12	CM, BP, FO
1440	55–62	514–554	48,347	0	CM
1441	63–69	462–467	47,878	0	RI
1690*	01–04	490–517			CM, BP
1691*	05–08	486–540			FO, LO
1692*	09–12	293–481			RI, DU, SB
1693*	13–16	320–500			BP, RI, DU, SB

* [illegible]

and Ross, 1986). Submersible positions and transect lengths were determined from LORAN C coordinates, while horizontal visibility was twice the radius (~9.1 m) of the lighted arc of bottom as seen by the forward observer several meters above the bottom.

The population size of adult crabs was estimated for an area encompassing the shallowest and deepest observations in each area by 4 km along the respective isobaths. Population size of this area was estimated from expansions of mean crab density from each habitat type to the proportion of habitat types among cross isobath transects or between survey transects.

RESULTS

Thermal Environment.—Water temperatures differed considerably between crab censusing operations in August 1986 and July 1987. Composite profiles of water column temperatures constructed from routine dive data, showed separate trends and minimal bottom water temperatures (Fig. 2). Temperatures of water at the bottom ranged from 13° to 15.5°C in 1987 and were near 7°C for all three dives in 1986. All temperatures in 1987 were warmer than those recorded at similar depths in 1986. Although temperatures in 1987 appeared more variable than those in 1986, they represented a larger number of samples distributed over a greater area of the slope and depth range than in 1986. Temperatures within the water column stabilized below about 300 m in 1986 and below about 400 m in 1987.

Description of Habitats.—The three areas surveyed during submersible operations in 1986 and 1987 were categorized into seven habitat types (Fig. 3). The flat-ooze habitat was the most frequently encountered habitat during crab censusing dives, occurring at depths from 405–567 m in 28% of the transects and accounting for 31% of the surveyed area. Although this habitat was somewhat variable in sediment composition, the flat ooze was generally characterized by foraminifera-pteropod debris mixed with larger shell fragments. Much of the sediment surface in the flat-ooze habitat had dark black precipitate, probably phosphorite, accu-

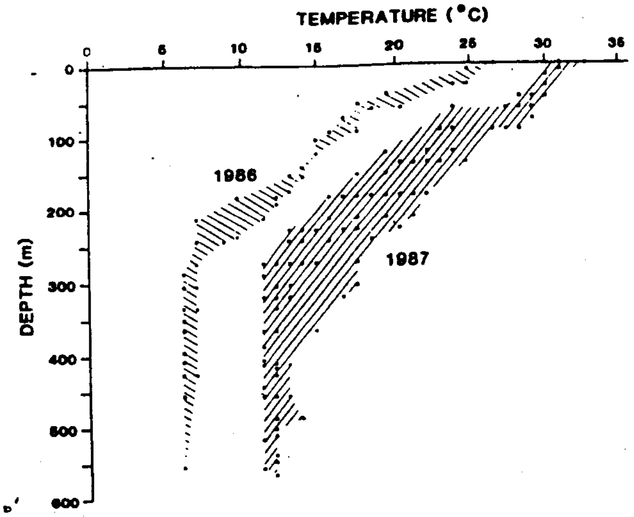


Figure 2. Temperature-depth profile for 1986 and 1987 submersible dives.

mulated in "windrow" like streaks (Fig. 3A), which suggested that some fine sediment transport was occurring. A northerly current velocity was 1.9–2.8 km·h⁻¹ over the flat-ooze habitat.

Distinct mounds, primarily of dead coral, were encountered at depths of 503–555 m and constituted 20% of the bottom surveyed on dives to count crabs. Coral mounds rose approximately 15–23 m in height above the surrounding sea floor and included several that were thinly veneered with a fine sediment and dead coral fragments, as well as a number that were thickly encrusted with live branching ahermatypic corals (*Lophelia prolifera* and *Enallopsammia profunda*) (Fig. 3B). Fan-shaped sponges, pennatulids and crinoids were oriented into the northerly 1.4–1.9 km·h⁻¹ current. The decapod crustaceans *Bathynectes longispina*, *Heterocarpus ensifer* and *Eumunida picta*, the black-bellied rosefish, *Helicolenus dactylopterus*, and the wreckfish, *Polyprion americanus*, were frequently sighted along transects in the coral mound habitat.

Several of the habitat types were characterized by current-generated structures such as ripples, scour marks, depressions and dunes with steep berms. The ripple habitat at depths of 419–539 m was encountered in over 19% of the area surveyed in 1986 and 1987. This habitat was characterized by sediments of coarse pteropod-foraminiferan fragments, streaked with black precipitate, asymmetric ripple marks, current crescents and occasional depressions of 1–2 m depths (Fig. 3C). The dune topography occurred from depths of 389 to 411 m, but constituted only 3% of the total area surveyed. Dunes were 4–5 m in height, with strongly rippled slopes facing the current on the southward sides and tops, and smooth steep scarps on the northward (leeward) sides (Fig. 3D). Organic debris and refuse were frequently sighted in the lee of dunes and in scoured depressions of the rippled habitat. Current velocities in the rippled and dune habitats were 1.9–2.8 km·h⁻¹ from 190°–220°.

The black pebble habitat occurred at depths of 481–564 m and was encountered over 12% of the surveyed bottom in 1986 and 1987. Bottom sediments were primarily globigerina ooze over which small, rough-textured, black pebbles of phosphorite were uniformly scattered (Fig. 3E). Pebbles occasionally graded into larger rocks (~15 cm) which frequently had live white coral attached. The black pebble habitat was observed most commonly near or between coral mounds, or in association with less common, low outcrops (Table 2).

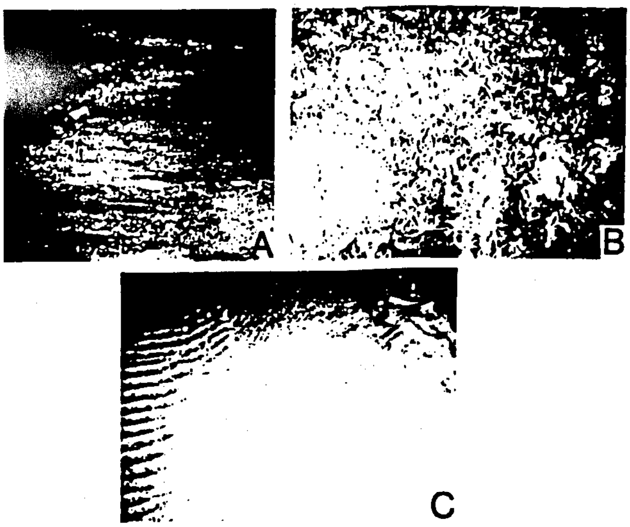
The low outcrop habitat occurred at depths of 503–512 m and constituted 3% of the surveyed area in 1986 and 1987. This habitat consisted of relatively flat globigerina ooze through which black pebbles and low-relief (10–30 cm), slab-like rocks were scattered. Many of the exposed rocks were undercut by currents and bioerosion with occasional invertebrates, including coral, attached to the flat top surfaces (Fig. 3F). *Polyprion americanus*, *Helicolenus dactylopterus*, and the decapod crustaceans, *Eumunida picta* and *Cancer borealis*, were common in this habitat. Current velocities ranged from 1.4–1.6 km·h⁻¹ from 190°–220°.

The soft-bioturbated habitat was observed on crab-censusing dives only in 1986 at depths from 413–475 m. This habitat was characterized by soft sediments of green globigerina ooze and extensive bioturbation in the form of worm tubes, shallow depressions, mounds and burrows of benthic organisms (Fig. 3G). The soft-bioturbated habitat occurred over 12% of the total area surveyed. The northerly current of this habitat was of low velocity (0.4–0.6 km·h⁻¹).

Density Estimates.—A total of 109 *Chaceon fenneri* were sighted over 583,480 m² of bottom surveyed on 85 submersible transects in 1986 and 1987 (Table 1). When transects were classified by habitat type, 27% of the golden crabs occurred in the flat-ooze habitat which comprised 31% of the total area surveyed. The flat-ooze habitat and the rippled habitat together accounted for 48% of the golden crab sighted and 50% of the bottom area surveyed (Fig. 4).

Density (mean no·1,000 m⁻²) was significantly different among habitats (Table 3) with highest values (0.7·1,000 m⁻²) noted among low outcrops which constituted only 3% of the bottom surveyed (Fig. 4). Lowest densities were associated with the dune habitat (<0.1·1,000 m⁻²) while densities for other habitats were similar (0.15–0.22·1,000 m⁻²). Analysis of variance for mean density among four 50-m depth-intervals found no significant difference (Table 4).

Population Estimates.—Estimates of the densities of adult crabs and the areas of each habitat type were expanded to determine population size within a 4 km area (along isobaths) bounded by the depth extremes of visual habitat confirmations (across isobaths) during all three dive years. The estimated crab populations for sampled sites were similar (Table 5), although estimates from Area A were smaller due to a lack of data from habitats shallower than 400 m. The two habitats associated with hard substrates, coral mound and black pebble habitats, support greater crab populations in Areas A (40% of the area's total population) and C (42%) than in Area B (27%). Estimates of crab populations from the combination of soft habitats, soft-bioturbated and flat ooze were spatially variable and ranged from 12% (Area C) to 62% (Area B). The habitat type of highest mean crab density, low outcrop, supported fewest number of crabs in Areas A and B where this habitat was infrequently encountered. The low outcrop habitat contributed greatly to the estimate in Area C, where it represented 10% of the expanded area. Estimates



: 3. Habitat types identified during submersible operations: A) Flat ooze—Flat globigerina ooze, y with accumulations of black precipitate. Ripple marks are occasionally seen. Crab shown is r *borealis*. B) Coral mounds—Raised areas of hard bottom with dead coral and patchy live coral *elia prolifera* and *Enallopsammia profunda*). C) Rippled—Globigerina ooze with ripples and onal 1–2 m depressions and black precipitate.

e crab population from habitats of high current velocity, dune and rippled, :sented less than 13% of the total crab abundance in any area.

Discussion

situ observations of *Chaceon fenneri* revealed that their abundance on the nental slope in the South Atlantic Bight differed with respect to bottom type. nfluence of bottom type on abundance was suggested by Wenner et al. (1987) information on sediment composition taken coincidentally with trap fishing ities. Catches were highest on substrates containing a mixture of silt-clay and niniferan shell; however, no golden crab were collected with limited trapping ss from low outcrop or coral rubble bottom. Submersible observations con- d low density of golden crab on coral mounds but showed that highest ties occurred in areas with low outcrops of rock where trapping was difficult often unsuccessful. Because the flat ooze and rippled habitats accounted for (50%) of the bottom surveyed, counts of crabs were highest for these habitats. ity, however, was low in the flat ooze and rippled habitats and was com- ile to that calculated in the coral mounds. While an association with soft rates has been noted for red crab, *C. quinquedens* (Wigley et al., 1975), *C. ri* appeared to occur on soft and hard bottom, with highest densities in areas

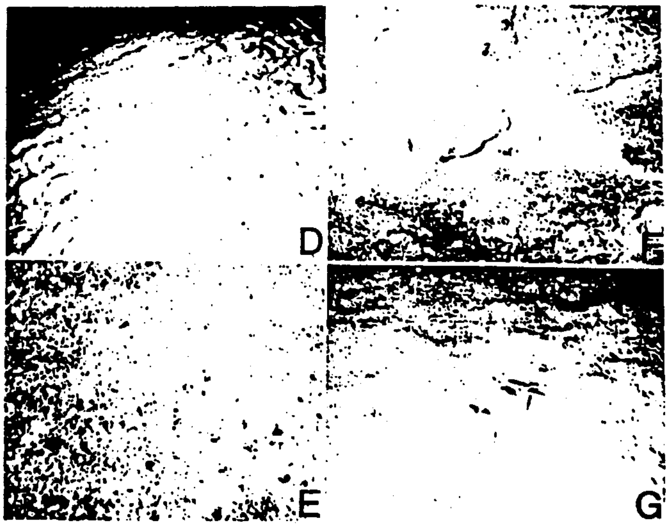


Figure 3 Continued. D) Dunes—Rolling dunes of globigerina ooze with heavily rippled up-current sides and smooth, sharply dropping down-current sides. E) Black pebbles—Pebbles resembling coal "clinkers" scattered over flat, globigerina ooze. F) Low outcrops—Intermittent rocks, black pebbles, and low relief ledges to which solitary corals are attached. Globigerina ooze occurs between rock outcrops. G) Soft-bioturbated—Globigerina ooze with small depressions and many vertically exposed worm tubes. Crab shown is *Chaceon fenneri*.

with low outcrops. High densities in areas that are difficult to trap may represent either a habitat preference, possibly because of increased foraging opportunities provided by a more diverse epifaunal and infaunal invertebrate community, or may simply be a result of decreased fishing mortality. A preference of *C. fenneri* for hard bottom habitats was reported in the Gulf of Mexico, where higher trap catches and densities of golden crab were noted from cobble, rock outcroppings, and vertical rock walls (W. Lindberg, University of Florida, 1987, pers. comm.).

The extent of suitable habitat for golden crab in the South Atlantic Bight can be estimated by comparing similarities between the habitat types identified in our study area and those reported further south. From Cape Fear, North Carolina to Savannah, Georgia bottom topography between 270 and 450 m is highly variable, with rocky outcrops, sand and mud ooze present (Low and Ulrich, 1983). Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270–450 m between St. Augustine and Cape Canaveral, Florida (30°N to 28°N). Those authors also characterized this same depth range as extremely irregular bottom with some smooth limestone or "slab" rock present.

Deep-water coral banks are not uncommon on the Florida-Hatteras slope (Zarudzki and Uchupi, 1968), where the major coral species include *Enallopsammia*

Table 2. Presence of habitat types within depth intervals of areas sampled (1986–1988). (CM = coral mounds; BP = black pebbles; DU = dunes; FO = flat ooze; LO = low outcrop; RI = ripples; SB = soft-bioturbated)

Depth zones (m)	Area A	Area B	Area C
300–325		SB	DN
326–350		SB	SB, RI
351–375		SB	SB
376–400		SB	SB
401–425	SB	SB, FO	DU, RI
426–450		SB, FO	DU, RI
451–475	SB	DU, RI	FO, BP
476–500		DU, FO	BP
501–525	FO, RI, CM	FO, BP, CM	BP, LO
526–550	FO, BP, CM	FO, LO, CM	CM*
551–575	FO, BP, CM		
576–600	FO, BP, CM		

* Transects near given area.

profunda and *Lophelia prolifera* (Cairns, 1979; Cairns and Stanley, 1981). Neumann and Ball (1970) described coral mounds off Miami as muddy-sand ridges, 12–15 m in height, that were topped by thickets of the branching deepwater ahermatypic corals *Lophelia*, *Madrepora* and *Dendrophyllia*. These coral mounds were found at depths of 719–825 m on the eastern scarp of the Miami Terrace (Neumann and Ball, 1970), at 1,000–1,300 m on the lower slope north of Little Bahama Bank (Mullins et al., 1981), and from 600 to 700 m along the base of Little Bahama Bank and out into the northeastern Straits of Florida (Neumann et al., 1977). Coral mounds in those areas were considerably deeper than those that we observed and had smaller patches of living coral.

Exposed bedrock several cm to 15 m in height, with a cap of hard black rock, exists between depths of 457–719 m off Florida (Neumann and Ball, 1970). The low relief outcrops we observed, however, occurred in a more limited depth range (466–512 m), and no high relief structures were found. At depths of 457–652 m, Neumann and Ball (1970) noted that smooth black nodules the size of "stove coal" littered the substrate. This feature is comparable to our black pebble habitat in a similar depth range. The dune habitat seen between 389 and 472 m on our transects consisted of structures that were higher than, and oriented in the opposite direction to, the southward facing 0.3–1 m sand ridges described at depths of 550–600 m off Miami by Neumann and Ball (1970). Current lineations in the form of ripple marks, scours, and crescents were observed from 600 to 661 m, while north-south streaking similar to that which we observed was frequently noted from 680 to 825 m by Neumann and Ball (1970). In addition to the differences in depth between their study area and our ripple habitat, the southerly flow along the slope of the Miami Terrace noted by those authors was opposite to that which we observed.

The deeper distribution of habitat types off Miami, as compared to depths for the corresponding type off South Carolina, suggests that the depth distribution of golden crab may change with latitude. Although Neumann and Ball (1970) saw numerous large crabs, tentatively identified as *Chaceon*, in shallow elongate trenches along their transects (457–719 m on the Miami Terrace), commercial trapping efforts off southeast Florida are generally concentrated at shallower depths (215–240 m; W. Lindbergh, University of Florida, 1987, pers. comm.). No information

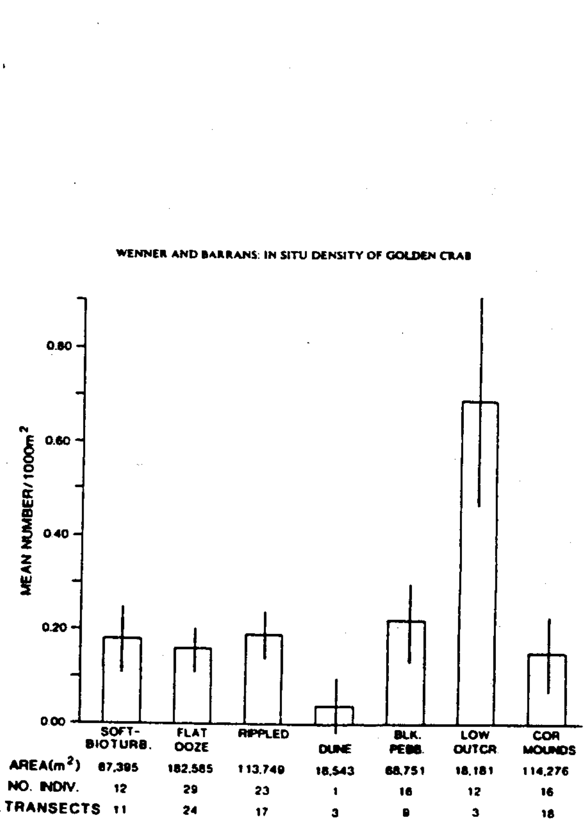


Figure 4. Density of golden crab among seven habitat types surveyed by submersible.

is available on bottom type in this region, but the continental slope is steep and may have ridges and rock habitats similar to more northerly shelf-edge reefs and prominences reported by Avent et al. (1977). At comparable depths in our study sites, catches were dominated by jonah crab, *Cancer borealis* (Wenner and Ulrich, unpubl.). The abundance of golden crab at shallower depths off southeastern Florida may be somewhat anomalous and needs further study to ascertain the physical and biological factors affecting distribution of golden crab there. || SEFL

The density of golden crabs calculated from in situ counts along our transects was surprisingly low compared to values reported in the literature for red crab, *C. quinquedens*. Using photographic methods to estimate density, Wigley et al. (1975) determined that the density of red crab could be as high as 258–282·ha⁻¹ in 320–640 m depths off southern New England. The much lower density (1.9 individuals·ha⁻¹) of golden crab in our study area suggests that golden crab stocks may be substantially lower than those of red crab.

Table 3. Analysis of variance comparing densities (No.·1,000 m⁻² of *Chaceon fenneri* among seven habitats. Variances were homogeneous by Bartlett's test ($\chi^2 = 10.0$, $P > 0.05$)

Source of variation	df	MS	F	P
Habitat	6	0.149	2.52	0.03
Error	78	0.059		

Table 4. Analysis of variance comparing mean densities (No.·1,000 m^{-2}) of *Chaceon fenneri* among 50 m depth intervals. Variances were honogeneous by Bartlett's test ($\chi^2 = 7.16$, $P > 0.05$)

Source	$\bar{y}$	$S_{\bar{y}}$	N	df	MS	F	P
Depth Intervals (m)							
				3	0.005	0.073	0.97
<400–450	0.19	0.05	21				
451–500	0.16	0.04	20				
501–550	0.20	0.05	37				
551–600	0.19	0.09	7				
Error				81	0.066		

The crab populations in small areas of 26–29 km^2 between 300–500 m depths off Charleston was estimated between 5,000 and 6,000 adult crabs. These estimates are much lower than the highest population estimate (~22,400·km^{-2} for a 37.34 km^2 area in 360–540 m) derived from a trap survey of *C. quinquedens* on the Scotian shelf by Stone and Bailey (1980). The largest proportion of the estimated golden crab population came from the flat-ooze habitat in northern Area A, in the soft-bioturbated habitat in Area B and in the low outcrop habitat in southern Area C. These apparent spatial differences in crab abundance by habitat type may reflect our inability to measure comparable depths and habitat types among areas due to limited dive time or inaccurate estimates of the proportion of habitats between survey transects that were parallel to isobaths.

More accurate estimates of the absolute abundance of *C. fenneri* would result from the incorporation of improvements into future studies. Improvements could include: (1) application of recent counting, measurement and analytical techniques into the sampling design, and (2) improved and uninterrupted quantification of the distribution of each habitat type across isobaths.

Application of correction factors, which can be calculated from measurements of right angle distances or visual zones (Patil et al., 1979; Quinn and Gallucci, 1980), may improve accuracy of visual counts which decreases with distance from the observer, i.e., the strip width of Sale and Sharp (1983). Once corrected densities

Table 5. Estimates of *Chaceon fenneri* abundance and percent of the area's total population by habitat type

	Habitats							
	FO	CM	RI	DU	BP	LO	SB	Total
Area A								
Area ($m^2 \times 10^6$)	8.5	0.8	1.9	0.5	7.3	–	4.7	23.7
Abundance ($\times 10^3$)	13.6	1.2	3.6	0.2	16.0	–	8.4	43.0
% of area's population	31.7	2.7	8.3	0.4	37.2	–	19.6	99.9
Area B								
Area ($m^2 \times 10^6$)	6.0	7.7	1.4	0.7	0.9	0.3	11.8	28.8
Abundance ($\times 10^3$)	9.7	11.6	2.6	0.3	2.0	2.2	21.2	49.6
% of area's population	19.5	23.4	5.3	0.6	4.0	4.4	42.8	100.0
Area C								
Area ($m^2 \times 10^6$)	–	7.8	3.2	3.2	5.7	2.7	3.9	26.5
Abundance ($\times 10^3$)	–	11.7	6.1	1.3	12.6	18.8	7.1	57.6
% of area's population	–	20.4	10.6	2.2	21.9	32.6	12.3	100.0

are stratified (by habitat), an optimal stratified-random sampling design should be developed based on the proportion of habitat area and the variance associated with mean densities as was done by McCormick and Choat (1987).

An efficient method to obtain estimates of the proportional size of each habitat type within an area, especially in depth-related habitats, may be to conduct visual transects across (perpendicular to) the isobaths of the given area as was attempted in 1988 of this study. Additional submersible time would be required to assure that all necessary measurements are obtained, including estimates of submersible drift during descent in strong currents. Quantified habitat/spatial relationships could then be applied to the optimum sampling design and extrapolation of density values to more accurate estimates of absolute abundance.

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DIFFERENTIAL ALGAL CONSUMPTION BY THREE SPECIES OF *FISSURELLA* (MOLLUSCA: GASTROPODA) AT ISLA DE MARGARITA, VENEZUELA

Craig J. Franz

ABSTRACT

Visual observations and gut analyses were used to determine types of food ingested by *Fissurella nimbosa* (Linnaeus, 1758), *F. nodosa* (Born, 1778), and *F. barbadensis* (Gmelin, 1791) at Isla de Margarita, Venezuela. Although these animals have a wide variety of algal sources from which to select and on which they appear to feed in an opportunistic fashion, specific food preferences exist. *Fissurella nodosa* prefers encrusting microalgae and diatoms; *F. nimbosa* ingests laminar sheets of predominantly brown algae; *F. barbadensis* feeds on a wide variety of algae but often selects coralline algae of which it ingests entire branches. In zones of overlap, it is hypothesized that competition for food among *Fissurella* species is minimal due to resource allocation through food preference. Laboratory experiments indicate that all three congeners can ingest a greater variety of algal types than they normally consume in the field. Differential food consumption indicates significantly more elaborate niche partitioning among tropical intertidal *Fissurella* than was previously known.

Studies of comparative feeding among congeneric predators may provide insight into the manner by which organisms partition their environment. This partitioning may be achieved through spatial segregation, temporal allocation, or dietary preference. In situations of spatial overlap and temporal feeding similarity, a unique opportunity exists to evaluate the way in which food preferences may help establish an individual's niche. In these circumstances, dietary studies of co-occurring congeners provides information concerning the partitioning of community food resources.

Many prosobranch groups utilize benthic algae as a food source (Fretter and Graham, 1962; Sutherland, 1970; Lubchenco, 1978; Underwood, 1980; Bosman and Hockey, 1988). Although competition and physical factors may regulate the vertical distribution of algae in the intertidal zone, grazing may be equally important (Hawkins and Hartnoll, 1983). Most limpets are classified as generalist feeders which utilize available microflora and detritus (Graham, 1955; Purchon, 1968; Branch, 1981); nevertheless, some limpets eat macroalgae (Eaton, 1968; Goss-Custard et al., 1979). Feeding preferences of limpets may differ considerably, and these differences can exist even among congeners. For example, *Lottia* (=*Acmaea*) *limatula* Carpenter, 1864 feeds mostly on the encrusting red and coralline algae *Hildenbrandia, Peyssonellia, Lithophyllum* and *Lithothamnion* (Eaton, 1968), whereas a sympatric congener, *Lottia* (=*Acmaea*) *pelta* Rathke, 1833, feeds on numerous macroscopic frond algae such as *Rhodoglossum affine* Harvey, *Pelvetia fastigata* J. Agardh and *Egregia menziesii* Turner (Craig, 1968).

Only a few studies have included the feeding habits of species in the genus *Fissurella* Bruguière, 1789; existing information for this group is incomplete and confusing. Kohn (1983) stated that fissurellids are mainly predators which graze on sessile invertebrates. However, Ward (1966) found that *F. barbadensis* in Barbados commonly ingests cyanobacteria [blue-green algae], including *Lynghya, Oscillatoria, Phormidium* and *Anacystis*, and green algae such as *Chlorochytrium, Ulothrix, Cladophora* and *Precursaria*. Castilla (1981) reported that several species of Chilean *Fissurella* feed on benthic algae, but did not identify these algae. One

Appendix N. Exploration for Golden Crab, *Geryon fenneri*, in the South Atlantic Bight: Distribution, Population Structure and Gear Assessment (1987)

EXPLORATION FOR GOLDEN CRAB, *GERYON FENNERI*, IN THE SOUTH ATLANTIC BIGHT: DISTRIBUTION, POPULATION STRUCTURE, AND GEAR ASSESSMENT[1]

ELIZABETH L. WENNER,[2] GLENN F. ULRICH,[3] AND
JOHN B. WISE[2]

ABSTRACT

Exploratory trapping for golden crab, *Geryon fenneri*, was conducted from 5 August 1985 to 21 February 1986 off South Carolina and Georgia. A buoyed system with strings of six traps (three side-entry Fathoms Plus and three top-entry Florida traps) was fished in six depth strata: 274-366 m, 367-457 m, 458-549 m, 550-640 m, 641-732 m, and 733-823 m. A total of 3,152 *G. fenneri* (2,661.9 kg) were collected at sampled depths between 296 and 810 m. The only other numerically important species caught was the jonah crab, *Cancer borealis* (864 individuals, 227.5 kg).

Catches of golden crab were highly variable between strata. Catch per trap increased from 1.6 crabs (1.67 kg) in the shallowest stratum sampled to a maximum abundance of 22.3 crabs/trap (18.04 kg/trap) in the 458-549 m depth zone. Catches abruptly declined in the deeper strata sampled.

Number of golden crab per trap (1.7:1) and weight per trap (1.6:1) in the Florida trap exceeded that in the Fathoms Plus trap for all completed sets. Traps yielded golden crab as small as 85 mm CW but the greatest proportion of crabs was >100 mm CW. Over 90% of all individuals exceeded 114 mm CW which is the minimum size of red crab, *G. quinquedens*, accepted for commercial utilization. Male golden crab were more numerous and larger than females.

Crabs of the genus *Geryon* (Brachyura: Geryonidae) are deepwater inhabitants of the Atlantic, Indian, and Pacific Oceans (Rathbun 1937; Monod 1956; Christiansen 1969; Manning and Holthuis 1981). Species reported off the United States in the western Atlantic and Gulf of Mexico include the red crab, *G. quinquedens* Smith, and the golden crab, *G. fenneri* Manning and Holthuis. At the time *G. fenneri* was described (Manning and Holthuis 1984), its geographic and bathymetric distribution included the continental slope off eastern Florida, the Florida Straits, and the Gulf of Mexico. An exploratory fishing effort in 1984 collected the first known specimens of golden crab off South Carolina[4], and it is now known that golden crab occur in waters off Bermuda (Luckhurst in press).

Both *G. quinquedens* and *G. fenneri* have been the target of limited and sporadic commercial fishing efforts off the east coast of the United States (Gerrior 1981), in the Gulf of Mexico (Otwell et al. 1984; National Marine Fisheries Service 1986[5]), and off Bermuda (Luckhurst in press). Although much information is available concerning the biology and commercial fishery of red crab (summarized by Gerrior 1981), biological information on golden crab is more limited. Otwell et al. (1984) demonstrated exploratory trapping and processing techniques for golden crab from the Gulf of Mexico.

The initiation of a small commercial crabbing enterprise during 1984 in South Carolina yielded promising quantities of golden crab[6]. We began the present study to determine the fishery potential, compare trap designs, delineate bathymetric distribution, and describe the biology of golden crab in the South Atlantic Bight. This report documents results on catch rates, size and sex compo-

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[4]South Carolina Wildlife and Marine Resources Department, unpubl. data, courtesy Charles Wenner, Marine Resources Research Institute, Charleston, SC.

[5]National Marine Fisheries Service. 1986. Species profile: deep red crab, *Geryon quinquedens*, Smith and golden crab, *Geryon fenneri*, Manning and Holthius, 1984 from the southeastern U.S. south of Cape Hatteras, N.C. U.S. Dep. Commer. Natl. Mar. Fish. Serv., NOAA, Pascagoula Lab., Latent Resour. Rep., 17 p.

[6]H. Holley, commercial fisherman, Charleston, SC, pers. commun. 1985.

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sition of *G. fenneri* as a function of depth and trap type, and examines aspects of adult life history and reproductive biology of this species in the South Atlantic Bight.

METHODS

Cruises were made during the period from 20 June 1985 to 21 February 1986 on board the South Carolina Wildlife and Marine Resources Department (SCWMRD) research vessels *Oregon* and *Lady Lisa*, and the NOAA ship *Chapman*. All vessels were equipped with large capacity hydraulic systems and a heavy duty pot hauler.

Two commercially available trap designs were used to sample crabs. The Fathoms Plus[7] traps are oval (85 cm long × 66 cm wide × 30 cm high) and constructed of injection molded plastic. The trap has two side-entry funnels that can be enlarged by removing more of the plastic funnel's inner lip. The original, oval funnel opening is 10 cm × 20 cm. Both funnels were cut out to a maximum opening size of 14 cm × 22 cm. Traps were weighted with chain, making the total weight of each trap 11 kg. The Florida trap is an injection molded, high-impact plastic version of a Florida spiny lobster trap (82 cm long × 61 cm wide × 45 cm high). The top of the trap is constructed of wood lathing to provide a biodegradable escape panel. The top entrance funnel has adjustable panels and is 20 cm × 25 cm in the most open position, as fished throughout the study. Two strips of poured concrete in each end of the trap provided ballast, making the total weight of the trap about 22.7 kg.

Traps were baited with 1.2-1.6 kg of clupeids. Three Florida and three Fathoms Plus traps were alternately attached at 61 m intervals to 365.6 m of groundline. The groundline was constructed of 8 mm diameter Iceline, a dacron, polyethylene line that has a high tensile strength relative to its diameter. A small weight consisting of ~9.0 kg of chain was attached to one end of the groundline and an anchor (~25 kg) was attached to the buoyline end of the gear. Buoy lines were 366 m sections of 8 mm Iceline joined together to achieve at least a 2:1 ratio of line to water depth. Four inflatable net buoys and a spar buoy with radar reflector were attached to the buoyline.

Six depth strata were sampled between lat. 29°53.1′-32°20.0′N and long. 78°01.5′-79°24.8′W: 274-366 m (stratum 1), 367-457 m (stratum 2), 458-549 m (stratum 3), 550-640 m (stratum 4), 641-732 m (stratum 5), and 733-823 m (stratum 6). Three sets of six traps each were made approximately 1-2 km apart within a depth stratum over a 24-h period. Sampling locations for each set were selected by making fathometer transects of the potential fishing area to determine depth and bottom type. Because of bad weather and logistical constraints all strata did not receive equal effort (Table 1).

The first trap type on the groundline was randomly selected with trap type alternating until six traps (three of each type) were attached. The exception to this arrangement occurred in the deepest stratum (733-823 m) where only the Fathoms Plus trap was used.

Fishing duration was standardized at 20 hours; however, poor weather conditions and logistical considerations altered this. Average fishing duration within strata exceeded 17 hours (Table 1).

Bottom temperature was determined in each depth stratum by reversing thermometers. Bottom sediments were sampled by a geological rocket grab for each group of three sets made in an area. Sediments retrieved were frozen on board and examined under a microscope for gross characterization in the laboratory. Sampling depth and location were recorded at deployment of the anchor.

Decapod crustaceans in each trap were identified, counted, and weighed. Catches from damaged traps or those sets that moved due to currents were excluded from analyses of distribution and abundance, but were included in biological studies of size and sex composition. Each golden crab was individually sexed, measured to the nearest millimeter (carapace width, CW, distance between the tips of the fifth lateral spines; carapace length, CL, distance from the diastema be-

TABLE 1.—Mean, standard deviation, minimum, and maximum fishing duration of trap sets, for *Geryon fenneri*, within six strata sampled from August 1985 to March 1986.

Stratum	No. sets	Fishing duration (h) $\bar{y}$	(s)	Min.	Max.
1	8	17.5	3.75	12.4	21.2
2	32	18.8	2.36	14.0	23.2
3	16	20.5	2.07	16.2	23.7
4	6	22.9	1.15	21.5	24.7
5	4	17.2	0.73	16.4	18.1
6	4	20.2	5.69	11.7	23.3

[7]Reference to trade names does not inply endorsement by the National Marine Fisheries Service, NOAA.

tween the rostral teeth to the posterior edge of the carapace, along the midline), and most were weighed to the nearest gram. The number of missing chelae and pereopods was recorded for each crab, as was molt condition and presence of chitinolysis and poecilasmatid barnacles, *Trilasmis inaequilaterale*, on the exoskeleton. Molt condition of *G. fenneri* was modified from criteria established by Beyers and Wilke (1980) for *G. quinquedens* (probably *G. maritae* Manning and Holthius) and consisted of five categories:

1) Hard - carapace at maximum strength, fouling by barnacles or chitinolytic bacteria minimal,
2) Hard old - carapace strong but heavily fouled by barnacles and abraded or blackened by chitinolytic bacteria,
3) Soft old - resorptive line along posterolateral sides of the carapace is weak; carapace heavily fouled as with hard-old condition,
4) Soft new - carapace soft or jellylike with no fouling, and
5) Hard new - carapace cracks under pressure and is not fouled.

Female *G. fenneri* were examined for evidence of egg extrusion and mating. Presence of eggs or egg remnants on pleopods and the size, shape, and physical condition of vulvae, as described by Haefner (1977), were noted. We examined seminal receptacles for presence of sperm or spermatophores and for relative size.

Ovaries from 72 of the 166 female *G. fenneri* captured were initially classified by relative size and color following the scheme described by Haefner (1977) for *G. quinquedens*. After gross classification of ovaries, tissues were removed for histological preparation and examination in order to describe ovarian structure and validate assigned ovarian stages. Tissues were fixed for at least 48 hours in 10% seawater formalin. After fixation, tissues were dehydrated, cleared, and embedded in paraffin. Sections were cut at 6-9 μm and were stained with Gill's hematoxylin and counterstained with eosin-Y. Oocytes from *G. fenneri* were measured using an ocular micrometer.

Testes and vas deferentia from three *G. fenneri* were fixed for 24 hours in 2.5% glutaraldehyde, rinsed in cacodylate buffer, and dehydrated in ethanol. Tissues were then critical-point dried, sputter coated, and examined using a Jeol JSM-35C scanning electron microscope (SEM).

RESULTS

Distribution and Relative Abundance

The 70 valid sets (416 individual trap observations) caught 3,152 *G. fenneri* (2,661.9 kg) at sampled depths between 296 and 810 m. The only other numerically important species caught was the jonah crab, *Cancer borealis* (864 individuals, 227.5 kg).

Catch per trap increased from 1.6 crabs (1.67 kg) in the shallowest stratum to a maximum abundance of 22.3 crabs/trap (18.04 kg/trap) in the 458-549 m depth zone (Fig. 1). Catches then abruptly declined with increasing depth. The absence of golden crabs in traps fished between 550 and 640 m appears to be related to unsuitable

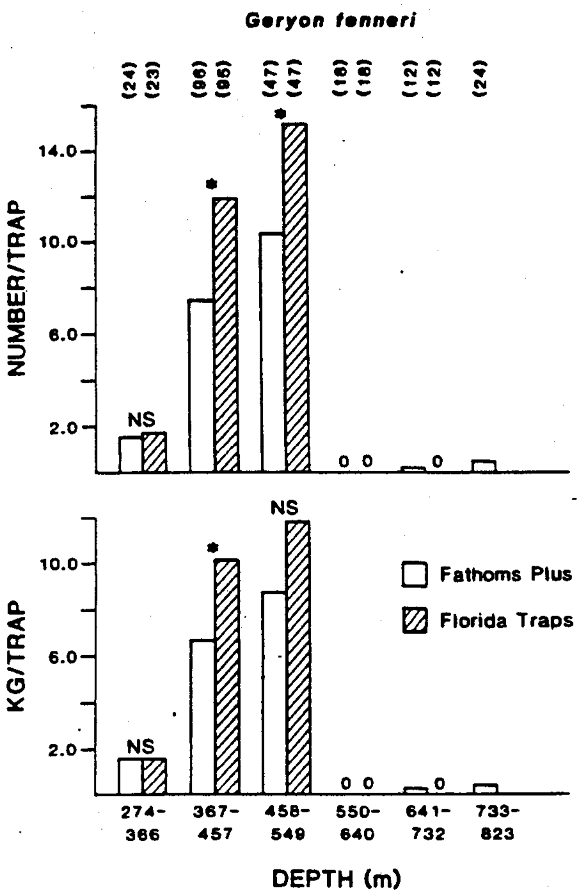


FIGURE 1.—Catch per trap of *Geryon fenneri* for six depth strata sampled. Effort (number of traps) is shown in parentheses. Statistical significance of catches between trap types, as determined by two sample *t*-test, is indicated by * ($P < 0.05$). NS indicates no significant difference in catch rates between the two trap types.

sediments at sites in this stratum since grab samples contained coral fragments and rubble. At shoaler locations where golden crabs were abundant, sediments were a mixture of soft silt-clay, molluscan shell fragments, and foraminiferan tests. Temperatures at sites where golden crabs were collected ranged from 7.14° to 9.15°C.

The number of golden crab per trap (11.4) and the weight of golden crab per trap (9.37 kg) in the Florida trap exceeded that in the Fathoms Plus trap (7.0 individuals, 6.16 kg) for all combined sets (Table 2). Statistical results by strata using the two-sample t-test or an approximate t-test when variances were heterogeneous (Sokal and Rohlf 1983), indicated significantly more crabs were collected with the Florida trap than with the Fathoms Plus trap from 367 to 457 m (stratum 2) and from 458 to 549 m (stratum 3) (Fig. 1, Table 2). Weight per trap was significantly different for the 367-457 m stratum only.

Size and Sex Composition

Male *G. fenneri* were significantly more numerous than females, outnumbering them by ~18:1. No ovigerous females were collected during the sampling period. Dominance of males was statistically significant for strata 1-3 (Table 3). In these depth strata, males were 20 times as numerous as females. In depths of 550-732 m, a male was the only crab collected. In the deepest stratum sampled (733-823 m), females significantly outnumbered males 2.9:1. Although the Florida trap caught significantly more crabs than the Fathoms Plus trap overall, no significant difference was noted in the number of female crabs between those two trap types (χ^2 test, $P > 0.5$).

The 3,217 golden crabs which were measured ranged from 85 to 193 mm in carapace width and weighed from 100 to 2,109 g. Average weight of male golden crab collected during the study was 927 g ($s = 373.448$, $n = 1{,}640$) while average weight of females was 443 g ($s = 289.385$, $n = 86$). Carapace width-frequency distribution for *G. fenneri* gave modes at 155 mm for males and 100 mm for females (Fig. 2). The largest crab collected measured 193 mm and weighed 2,091 g.

Linear least-squares and functional regression equations (Ricker 1973; Sokal and Rohlf 1983) relating carapace length and live wet body weight with width are in Table 4. Width-weight relationships were calculated from data on individuals that were not missing appendages.

Of the 3,183 golden crabs examined for missing appendages, 2.4% were missing one or both chelae. Pereopods were missing from 307 individuals (9.6%).

Examination of carapace width and weight statistics for each depth stratum showed that mean size of male *G. fenneri* was greatest for the shallowest (274-366 m) and deepest (733-823 m) strata sampled (Table 5). For females, however, mean carapace width and weight were greatest in the deepest zone. At depths of peak abundance, mean carapace width ($t_s = 4.70$, $P < 0.001$) and mean body weight ($t_s = 2.70$, $P < 0.01$) of male crabs were significantly greater in the 367-457 m than in the 458-549 m depth stratum. No signifi-

TABLE 2.—Results of t-test (T_s) comparisons of mean number and weight (kg) per trap for two trap types (FM+ and FLA) fished in each depth stratum for *Geryon fenneri*. Standard deviation is noted in parentheses; * indicates significance at 0.05 level.

Stratum	Number/trap FM+	Number/trap FLA	T_s	Weight/trap FM+	Weight/trap FLA	T_s
1	1.6(1.92)	1.8(2.21)	0.14	1.66(1.912)	1.80(2.157)	0.14
2	7.5(5.96)	11.9(9.95)	2.16*	6.67(5.097)	10.02(7.651)	2.06*
3	10.4(5.08)	15.2(7.08)	2.22*	8.82(4.164)	11.84(4.752)	1.91
4	0	0	—	0	0	—
5	0.1	0	—	0.07	0	—
6	0.5(0.28)	—	—	0.43(0.321)	—	—
Total	7.0(5.98)	11.4(9.38)	8.51*	6.16(5.052)	9.37(7.078)	6.18*

TABLE 3.—Frequency of male and female *Geryon fenneri* within each depth stratum. Asterisks denote significant deviation ($P < 0.05$) from 1:1 by Chi-square analysis.

Sex	Strata (m) 274-366	367-457	458-549	550-640	641-732	733-823
Male	84*	1,790*	1,165*	0	1	11
Female	3	91	41	0	0	32*

cant differences, however, were noted in mean carapace width (t_s = 0.85, $P > 0.05$) and mean body weight (t_s = 1.48, $P > 0.05$) of females from these same strata.

Of the two traps used, the Fathoms Plus trap caught larger and heavier golden crabs than did the Florida trap. Mean carapace width ($\bar{y}$ = 143 mm, s = 19.69, n = 1303) of crabs in the Fathoms Plus trap was significantly larger than that of crabs in the Florida trap ($\bar{y}$ = 139, s = 20.21, n = 1914) [t_s = 5.478, $P < 0.001$]. A statistically significant difference was also noted for mean weight (Fathoms Plus: $\bar{y}$ = 928, s = 366.77, n = 775; Florida: $\bar{y}$ = 881, s = 377.69, n = 951) [t_s = 2.598, $P < 0.001$].

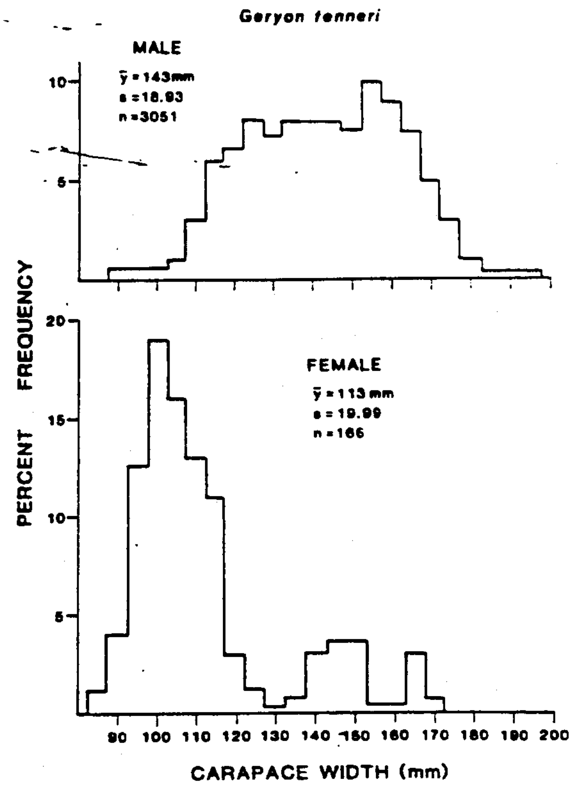


FIGURE 2.—Width-frequency distributions of male and female *Geryon fenneri* caught in traps. $\bar{y}$ = mean; s = standard deviation; n = number of individuals.

TABLE 4.—Least-square linear and geometric mean functional regression equations of carapace length (CL) and live body weight (WT) on carapace width (CW) for each sex of *Geryon fenneri*. Length and width units are millimeters while weight units are kilograms. All least square regressions were significant at α = 0.05.

Sex	Least squares equation	n	r^2	GM functional equation
Male	CL = −9.5 + 0.9 CW	3,042	0.95	CL = −11.9 + 0.9 CW
	$\log_{10}$ WT = −4.74 + 3.54 ($\log_{10}$ CW)	1,453	0.94	$\log_{10}$ WT = −4.99 + 3.66 ($\log_{10}$ CW)
Female	CL = 4.0 + 0.8 CW	141	0.92	CL = 0.7 + 0.8 CW
	$\log_{10}$ WT = −3.97 + 3.14 ($\log_{10}$ CW)	74	0.91	$\log_{10}$ WT = −4.27 + 3.29 ($\log_{10}$ CW)

TABLE 5.—Size and weight statistics of male and female *Geryon fenneri* from sampled depth strata. $\bar{y}$ = mean; s = standard deviation, n = number of individuals.

Sex	Stratum (m)	Carapace width (mm) $\bar{y}$	Min.	Max.	s	n	Weight (g) $\bar{y}$	s	n
Male	274-366	156	117	186	14.4	84	1,064	339.15	84
	367-457	144	100	190	18.1	1,790	937	354.03	983
	458-549	140	88	193	19.9	1,165	884	373.47	561
	550-640	—	—	—	—	—	—	—	—
	641-732	139	—	—	—	1	809	—	1
	733-823	161	135	181	11.7	11	1,112	225.22	11
Female	274-366	105	92	113	11.2	3	189	80.88	3
	367-457	105	85	145	8.6	91	265	103.13	35
	458-549	104	85	137	9.7	41	228	70.06	16
	550-640	—	—	—	—	—	—	—	—
	641-732	—	—	—	—	—	—	—	—
	733-823	149	117	170	13.6	31	768	201.09	32

Reproductive Biology

We obtained satisfactory histological sections from 39 of 72 female golden crabs examined. From histological and gross examination we described four ovarian developmental stages: 1) early, 2) intermediate, 3) advanced, and 4) mature.

In the early stage of development, the slightly lobate ovary is very small, transparent to white in color, and bounded by fibrous connective tissue. Oocyte diameter ranged from 58 to 92 μm with a mean of 75 μm (Fig. 3A). Nuclei and nucleoli are readily apparent in the early oocytes, as are follicle or accessory cells which surround each

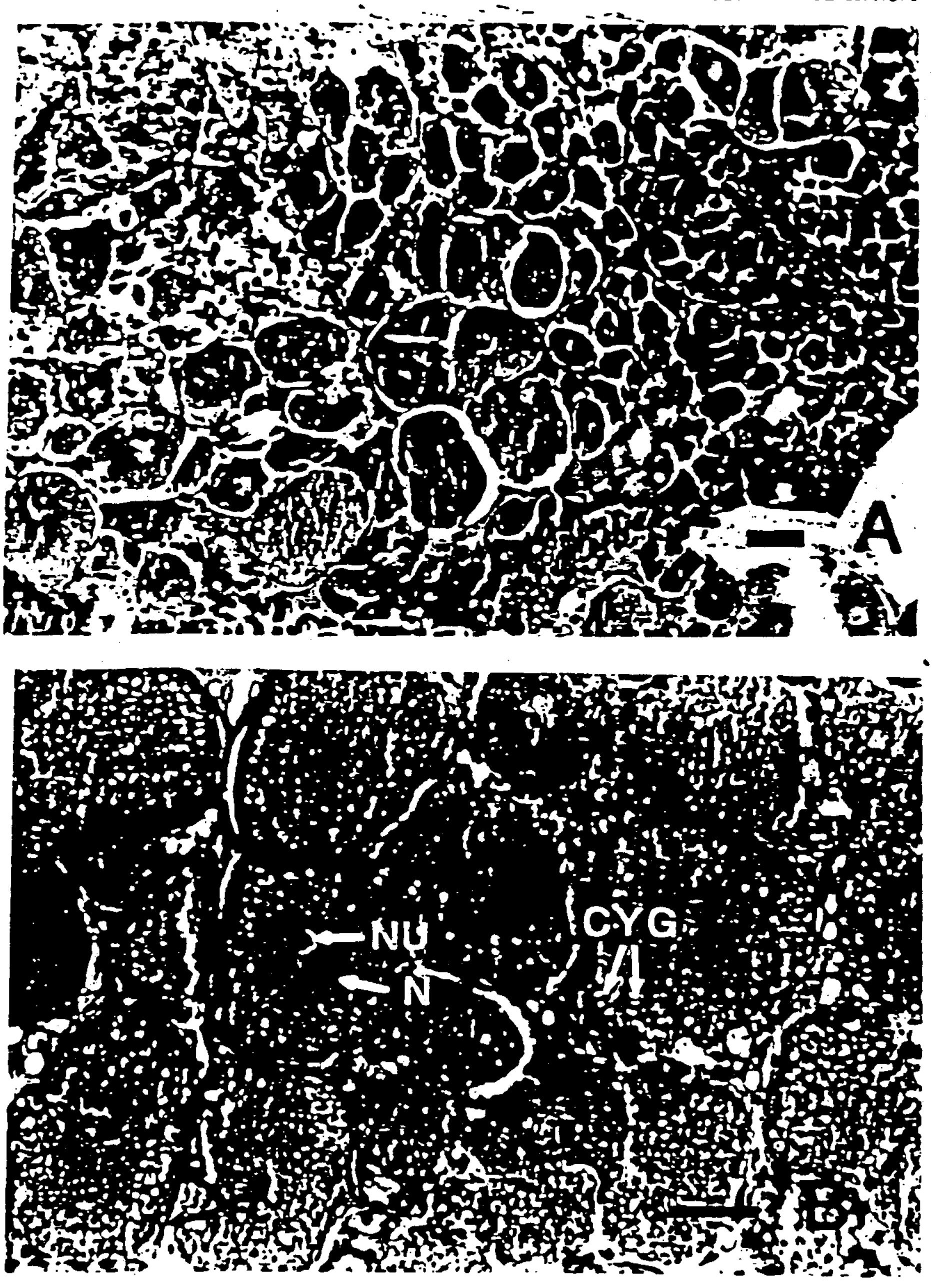


FIGURE 3.—Ovarian and testicular tissue of *Geryon fenneri*.

A. Ovarian tissue showing early (EOC) to intermediate oocyte (IOC) development. Oocytes range in size from 30 to 100 μm. Scale bar 60 μm.
B. Oocytes at the intermediate stage of development. Nucleus (N), nucleolus (NU), cytoplasmic yolk globules (CYG), follicle cells (FC). Oocyte size extremes are 100-125 μm. Scale bar 50 μm.

FIGURE 3.—*Continued.*

C. Oocytes in the advanced stage of development. Nucleolus (NU), cytoplasmic yolk granules (CYG). Oocytes 200-300 μm in size. Scale bar 30 μm.

D. A portion of a mature testis showing the seminiferous duct (SD) and testicular lobes containing spermatocytes (SC), spermatids (ST) and sperm (S). Accessory cell nuclei (AN). Scale bar 100 μm.

cell. In the larger oocytes, cytoplasmic vitellin globules indicative of vitellogenesis are present.

The intermediate stage ovary is yellow in color, has more pronounced lobation, and is larger than the early stage ovary. The diameter of oocytes ranged from 112 to 175 µm with a mean diameter of 145 µm. Most oocytes were undergoing vitellogenesis in this stage (Fig. 3B).

As the ovary matures to the advanced stage, the ovarian lobes become enlarged and the color becomes light orange to orange-red in color. The anterior portion of the ovary obscures the anterior hepatopancreas from dorsal view. Oocytes were 175-300 µm in diameter ($\bar{y}$ = 240 µm) and enlarge as vitellogenesis continues (Fig. 3C).

The mature ovary, brown to purple in color, is the dominant visible organ and obscures the hepatopancreas in dorsal view. Oocytes are filled with yolk globules and average 300-400 µm in diameter as vitellogenesis nears completion.

Size at sexual maturity was difficult to assess because of the small number of females collected. Overlap existed in the size of female *G. fenneri* in each stage of development.The carapace width of females in early ovarian development ranged from 85 to 116 mm ($\bar{y}$ = 104 mm, n = 27). Intermediate ovaries were present in females measuring 105-169 mm CW ($\bar{y}$ = 127 mm, n = 13) while advanced ovaries occurred at sizes from 110 to 136 mm CW ($\bar{y}$ = 123, n = 2). The 30 females with mature ovaries ranged from 97 to 169 mm CW ($\bar{y}$ = 141).

Five vulval forms were identified among the 142 females examined. Most of the females had immature vulvae (types a and b) suggesting that these crabs had not mated. The observed ovarian condition in a subsample (n = 26) of these females indicated that all had ovaries in an early stage of development (Table 6). Only one female (111 mm CW) with immature vulvae contained sperm in the seminal receptacles, indicating copulation had occurred. Type c vulvae were noted on two females, one with ovaries in early development and lacking sperm in the seminal receptacles while the other crab had mature ovaries and sperm present. Type e and f vulvae were found on the largest females collected, all of which had at least intermediate stage ovaries. Eight of the fourteen females with these vulval types whose seminal receptacles were examined had been inseminated.

Three male *G. fenneri* examined exhibited typical brachyuran reproductive morphology. The testes, which are dorsal to the hepatopancreas, were tubular and highly lobate. The testicular lobes, adjacent to the central seminiferous duct, contained spermatocytes, spermatids, and spermatozoa, suggestive of asynchronous development (Fig. 3D). In mature individuals, ripened spermatozoa were found in the seminiferous duct. Examination of the testes and vas deferentia by SEM revealed germ cells at various stages of development. Spermatids (Fig. 4A), surrounded by supportive tissue, were composed of a central nucleus framed in cytoplasm. With spermiogenesis, multiple projections or spikes form which are characteristic of developed sperm (Fig. 4A). Another portion of the same testis yielded a more advanced germ cell displaying well-defined cytoplasmic spikes (Fig. 4B). A sagittal section through the vas deferens revealed stellate spermatozoa (Fig. 4C), which had previously been embedded in this complex of supportive tissue (Fig. 4D).

TABLE 6.—Incidence of vulval type (after Haefner 1977) in relation to carapace width and gonadal condition of female *Geryon fenneri*. n = number of individuals examined.

Type	n	Carapace width (mm)	n	Gonadal condition
a	112	85-119	22	early
b	4	98-116	4	early
c	2	97-109	1	early
			1	mature
d	0	—	0	—
e	19	105-156	8	intermediate
			1	advanced
			9	mature
f	5	124-169	2	intermediate
			3	mature

Molt Condition and Fouling

Most (80%) of the 3,183 male and female *G. fenneri* were in the intermolt stage. Less than 1% of the 3,041 male golden crab showed evidence of having recently molted. The incidence of imminent or recently molted female golden crab was higher than that observed for males, with four individuals classified as premolt (soft-old) and two in the newly molted (soft-new) condition.

Most (95%) of the 3,183 *G. fenneri* examined for molt condition had blackened abraded areas on the exoskeleton, indicative of damage by chitinolytic bacteria. Exoskeleton damage was most prevalent on individuals in the intermolt (75%) and premolt (19%) condition.

DISCUSSION

Although the results of this study suggest that *G. fenneri* has a wide bathymetric occurrence in the South Atlantic Bight, the depth extremes for the species probably extend beyond those encompassed by our sampling design. Records of *Geryon* sp. and *G. affinis* (which were probably *G. fenneri*) from the Gulf of Mexico indicate a depth distribution of 365-1,455 m (Pequegnat 1970), while Luckhurst (in press) reported golden crabs from 786 to 1,462 m near Bermuda.

Although a broad bathymetric range for the species is likely, maximum abundance occurs between 367 and 549 m in our study area. This depth range coincides with that reported by Stone and Bailey (1980) for maximum trap catches of *G. quinquedens* along the Scotian Shelf and approximates the limits (320-530 m) determined by Wigley et al. (1975) by trawl and photographic methods to be most productive for that species off the northeastern United States.

Information on sediment composition taken coincidentally with fishing activities suggests that abundance of both *G. fenneri* and *G. quinquedens* is influenced by sediment type at these optimum depths. Our catches were highest on substrates containing a mixture of silt-clay and foraminiferan shell. In contrast, no golden crab were collected on rock and coral rubble bottom such as was encountered in the 550-640 m stratum. Other studies have described an association of *G. quinquedens* with soft substrates. Wigley et al. (1975) noted that bottom sediments throughout the area surveyed for red crab from offshore Maryland to Corsair Canyon (Georges Bank) consisted of a soft, olive-green, silt-clay mixture. If golden crabs preferentially inhabit soft substrates, then their zone of maximum abundance may be limited within the South Atlantic Bight. Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270-450 m between St. Augustine and Cape Canaveral, FL (30°N and 28°N). This same depth range from Savannah, GA to St. Augustine was generally characterized by Bullis and Rathjen (1959) as extremely irregular bottom with some smooth limestone or "slab" rock present. Our study indicates, however, that the bottom due east between Savannah and St. Catherines Island, GA at 270-540 m consists of mud and biogenic ooze. Further north from Cape Fear, NC to Savannah, bottom topography between 270 and 450 m is highly variable with rocky outcrops, sand and mud ooze present (Low and Ulrich 1983). Additional information on sediment type during future fishing efforts will be necessary before any validation of sediment preference by golden crab can be made.

The catch data for golden crab in our survey compares favorably with catch rates reported by Otwell et al. (1984) in the Gulf of Mexico. Although their study was not intended to assess the resource, they reported mean catch per trap values of 7.4-8.4 for the nested design fished between 210 and 340 fathoms. Information on catch rates of red crab from trap surveys and the fishery is perhaps more relevant to our study. Ganz and Herrmann (1975) reported an overall unculled mean catch per pot of 40-93 red crabs off southern New England; their study used four types of double parlor offshore lobster pots. An average catch of 26.8 red crabs per trap (conical-top entry) was reported in 360-540 m depths on the Scotian Shelf by Stone and Bailey (1980). The only available information on weight per trap was provided by Gerrior (1981) who found seasonal catch rates that ranged from a low of 8.4 kg in March to a high of 11.1 kg per pot in June. Although comparison of catch per unit of effort between these studies is questionable because trap type and fishing duration, as well as physical features of the sampling areas differ, catch per trap of golden crab in depths of maximum abundance off South Carolina and Georgia appears promising.

Comparison of catches (no./trap) between the Fathoms Plus trap and the Florida trap clearly indicate superiority of the latter for golden crab. These two traps also differed in the size and weight of individuals caught, with larger and heavier golden crab occurring in the Fathoms Plus trap. Advantages of the Fathoms Plus traps for commercial fishing operations would include their lighter weight, ease of handling, and stackable configuration which conserves deck space. Differences observed between traps may be related to trap design which affects success of entry and maximum catch (Miller 1980) or behavioral interactions which affect probability of capture (Richards et al. 1983). Although no studies have been done to evaluate behavior of *G. quinquedens* or *G. fenneri* in regard to traps, responses of the spider crab, *Hyas araneus*, and the rock crab, *Cancer irroratus*, to top and side entry traps were reported by Miller (1980). He found success of entry by *C. irroratus* was greater, escapement was reduced, and fewer agonistic encounters occurred in top entry traps. In a complementary study, however, *Cancer productus* had highest

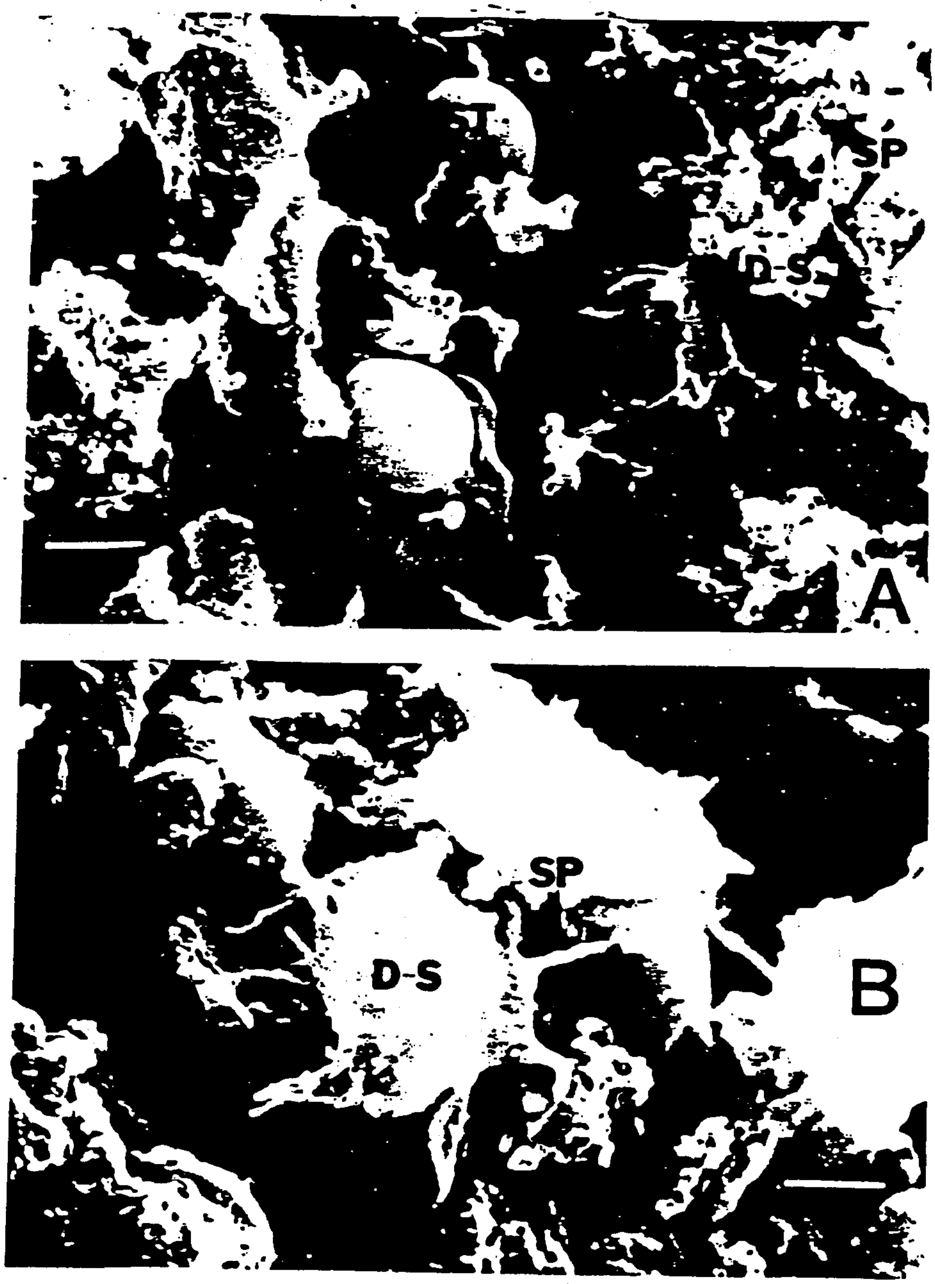
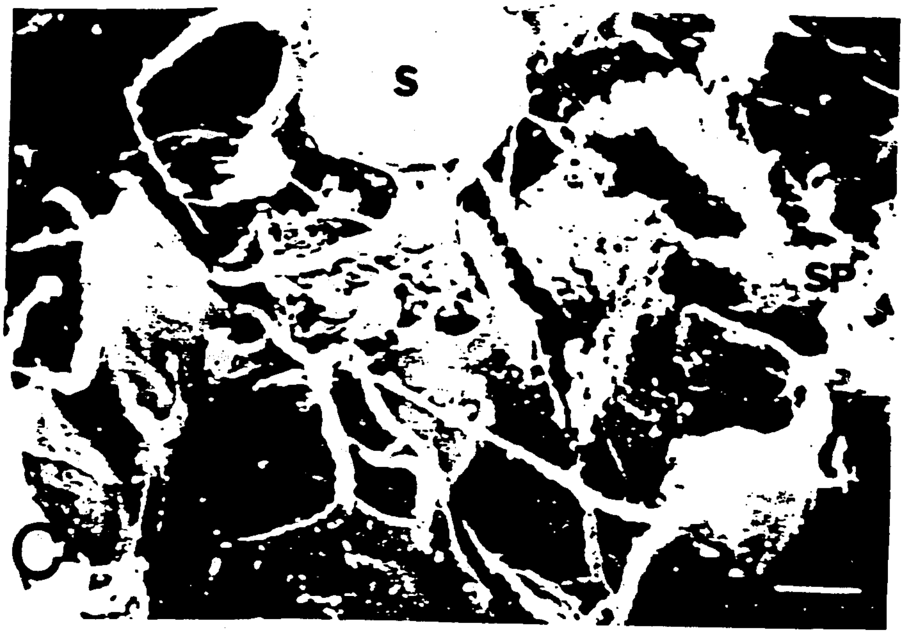


FIGURE 4.—Scanning electron micrograph of testis and vas deferens from male *Geryon fenneri*.
A. Testis: Maturing germ cells (spermatids, ST) surrounded by sustentacular tissue. Developing sperm (D-S), cytoplasmic spike (SP); × 3200. Scale bar 3 μm.
B. Testis: A developing sperm (D-S) possessing partial to fully formed cytoplasmic spikes (SP); × 3200. Scale bar 3 μm.



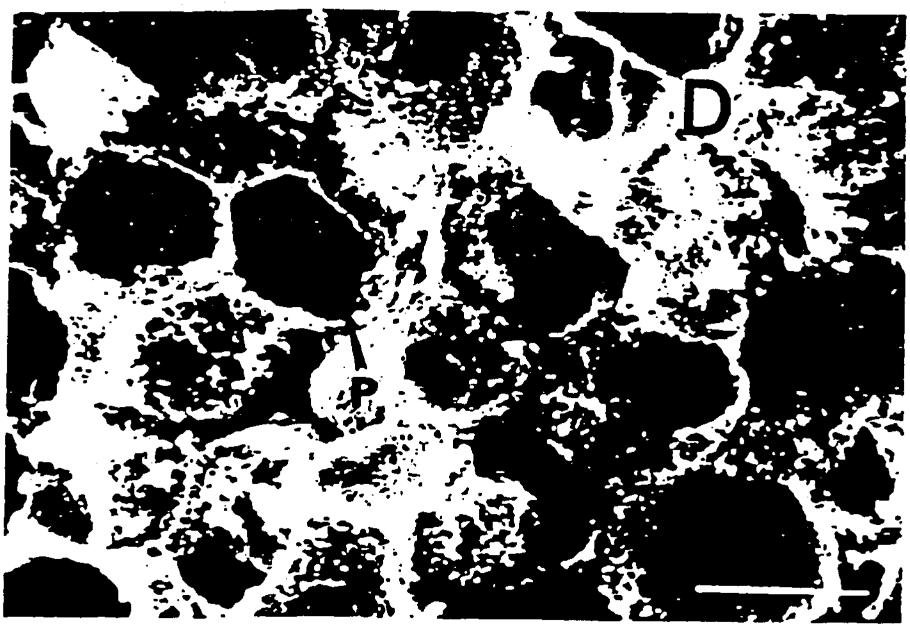


FIGURE 4.—*Continued.*

C. Vas deferens:- Mature multiple stellate sperm (S) showing cytoplasmic spike (SP): × 3840. Scale bar 2 μm.

D. Vas deferens: Pockets (P) within the vas deferens previously occupied by the mature stellate sperm: × 1600. Scale bar 10 μm.

success in entering a side entry trap whose entrances were parallel to the current (Miller 1978). Although our traps were deployed parallel to surface current, their orientation on the bottom relative to bottom current is unknown. We are assuming that golden crabs were successful in locating the entrance and were retained longer in the top entry Florida trap than in the Fathoms Plus trap. It is possible, however, that golden crab were equally or more successful in locating the side entrances of the Fathoms Plus trap but that escapement, especially of smaller golden crab, was higher. This would explain the capture of fewer but larger individuals by the Fathoms Plus trap.

The overwhelming dominance of males in this study contrasts with results reported in other geographic areas for golden crab. Luckhurst (in press) noted that sex ratio in his sample ($n = 244$) of *G. fenneri* from Bermuda waters was approximately 1:1. Otwell et al. (1984) noted that males tended to be more abundant at greater depths (>540 m) in the Gulf of Mexico; however, they cautioned that trap design may influence the percentage of male crabs caught. Commercial crabbers noted a decline in catch rates and number of male *G. fenneri* with increasing depth on the slope in the eastern Gulf of Mexico (National Marine Fisheries Service fn. 5). We also found increased abundance of females at greater depths, although our results are limited due to the small number of females collected. This is apparently not an artifact of sampling with only the Fathoms Plus trap in the deepest stratum since more females were collected in the Florida trap than with the Fathoms Plus trap when only strata 1-3 were considered. Segregation of the sexes by depth has been observed in several studies of *G. quinquedens*. Wigley et al. (1975) collected more female red crabs than males, but this dominance was limited to intermediate depths (320-503 m). Ganz and Herrmann (1975) similarly noted dominance by male red crab at depths >685 m off Rhode Island. This same pattern was noted for red crab in the vicinity of Norfolk Canyon where females were more abundant than males from depths <600 m (Haefner and Musick 1974; Haefner 1978). In Canadian waters, however, female red crabs were reported by Stone and Bailey (1980) to be considerably less abundant than males. Although they attributed this discrepancy to trap bias, another study in the same general area found females were present but highly contagious in distribution. Whether seasonal migrations related to mating or spawning occur as hypothesized by Wigley et al. (1975) for *G. quinquedens* remains to be substantiated. What is evident from our results is that male *G. fenneri* are dominant in depth strata where catch per unit of effort is highest.

Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migration such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al. 1982).

The size composition of golden crab from our study showed that crabs become trappable as small as 85 mm CW but that the greatest proportion of trapped individuals is >100 mm CW. Over 90% of all individuals collected exceeded 114 mm CW which is the minimum size of red crab accepted for commercial utilization (Wigley et al. 1975). A much smaller proportion (52%) of golden crab >114 mm was indicated in size-frequency distributions of trap-caught golden crab near Bermuda (Luckhurst in press). Although Otwell et al. (1984) did not present size and weight-frequency data for golden crab in the Gulf of Mexico, they found mean size of male crabs ranged from 155 to 163 mm with mean weight extremes of 1.07-1.15 kg, while females were smaller with mean CW ranging from 119 to 135 mm and mean weight extremes of 0.45-0.50 kg. These data and those from our study suggest that the average size of golden crab from the South Atlantic Bight and Gulf of Mexico is larger than the average size of red crab reported along the eastern United States and Canada. Wigley et al. (1975) reported average width of male *G. quinquedens* was 99 mm with an average weight of 413 g. Average width of all females from their study was 90 mm with a mean weight of 244 g. Comparisons of size composition between the two studies must be qualified, however, by a caveat that differences in sampling methods probably influenced sample statistics. The apparent larger size of golden crab may be better substantiated by maximum width and weight measurements, which for our study were

193 mm and 2,109 g, respectively. These values were markedly larger than those reported for red crab in the vicinity of Norfolk Canyon (Haefner 1978), off northeastern United States (Wigley et al. 1975), or the Scotian Shelf (Stone and Bailey 1980; McElman and Elner 1982).

The small number of females collected during the first year precludes any definitive statements regarding ovarian cycles or spawning patterns. Ovarian developmental stages are similar to those reported by Haefner (1977) for *G. quinquedens*. We also found his use of vulvae condition as an external indicator of copulation to be fairly reliable, but examination of the seminal receptacles for sperm or spermatophores provided the only true indication of mating. Tentative interpretations on ovarian development, vulval condition, and presence of seminal products suggest that females may become sexually mature at 97 mm CW. Haefner (1977) suggested that female *G. quinquedens* become sexually mature within the intermolt size of 80-91 mm CW.

A lack of ovigerous females in our first-year sampling effort could be indicative of a restricted spawning season similar to that reported for red crab (Haefner 1977; Wigley et al. 1975). Absence of ovigerous females from our samples, however, may be related to the small number of female golden crab collected.

Observations on molting and mating of a female (110 mm CW), which had been held in a refrigerated aquarium since February 1986 and had completed ecdysis in late May 1986, confirmed that female golden crab molt just before mating occurs. This behavior, as well as the observed premolt embrace, has been described for *G. longipes* (Mori and Relini 1979), although it has not been reported previously for either *G. quinquedens* or *G. fenneri*.

Stage of ecdysis is an important factor affecting meat condition and yield in golden crab. Crabs which have recently molted generally have a very poor meat yield and are not marketable[8]. Since most golden crab in the intermolt stage had blackened abraded areas or poecilasmatid barnacles on the exoskeleton, their presence was useful in distinguishing premolt from postmolt crabs which were brighter in color and had few abrasions.

[8]W. Lacy, Seafood Marketing Section, South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, pers. commun. 1985.

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Appendix O. Reproductive Ecology of Female Golden Crabs, *Geryon fenneri* Manning and Holthuis, from Southeastern Florida (1988)

REPRODUCTIVE ECOLOGY OF FEMALE GOLDEN CRABS, *GERYON FENNERI* MANNING AND HOLTHUIS, FROM SOUTHEASTERN FLORIDA

Robert B. Erdman and Norman J. Blake

ABSTRACT

Examination of deep-water female golden crabs collected monthly from the southeastern coast of Florida indicates an annual reproductive cycle with a single batch of eggs produced each year. Oviposition begins in late August and continues through October with eggs retained for approximately 6 months until hatching during late February and March. Sizes of ovigerous females examined ranged from 96 to 147 mm carapace width (CW). Extruded eggs averaged 540 μm in diameter, increasing to between 580 and 600 μm prior to hatching. Fecundity estimates range from 131,000 to 347,000 eggs with brood size highly correlated to CW. Changes in gonopore margins associated with molting and the onset of ovarian activity indicate that size at sexual maturity is between 85 and 100 mm CW. Although sampling depth ranges were limited, *Geryon fenneri* may display similar segregation by sex and size with depth as other species of *Geryon*.

Crabs of the genus *Geryon* are large brachyurans inhabiting the continental slope of the Atlantic, Indian, and Pacific Oceans (Manning and Holthuis, 1981; Rathbun, 1937). Three species are reported from the western Atlantic Ocean: *G. inghami* Manning and Holthuis, 1986, *G. fenneri* Manning and Holthuis, 1984, and *G. quinquedens* Smith, 1879; the latter two species have commercial value.

The red crab *G. quinquedens* has been the object of commercial fishing off the New England states and Canadian maritime provinces since the late 1960s (see Gerrior, 1981, for review). The biology of that species has been examined by various authors: depth distribution patterns (Haefner and Musick, 1974; Haefner, 1978; Wigley *et al.*, 1975), reproductive cycle (Gray, 1969; Haefner, 1977, 1978), mating behavior (Elner *et al.*, 1987), and the description of larval forms (Perkins, 1973).

The golden crab *Geryon fenneri* is also of commercial value and is the target of limited commercial trapping off the coast of the southeastern United States including the eastern Gulf of Mexico (Otwell *et al.*, 1984). Since late 1985, a small fishery has developed off the southeastern Florida coast with live animals sold to an increasing local market (Erdman and Blake, 1988). However, with the exception of the description of this species (Manning and Holthuis, 1984), relatively little is known of its biology.

We report on aspects of the reproductive biology of female *G. fenneri* collected monthly off the southeastern Florida coast. Data on the reproductive cycle, fecundity, mating, and size at sexual maturity were examined to acquire additional information on the biology of this commercially valuable species.

MATERIALS AND METHODS

Monthly samples were obtained from a commercial trapping vessel during the period February 1986 through January 1987. The fishing area was located due east of Fort Lauderdale, Florida, at approximately 26°10'N, 82°05'W, with fishing depths ranging from 215 to 235 m. All samples were obtained from Neilsen traps fitted with escape rings (see Erdman and Blake, 1988). Traps were deployed on bottom longlines adapted from gear illustrated by Otwell *et al.* (1984). Female crabs were randomly selected from the catch, packed in crushed ice, and returned live to the laboratory.

For each crab, carapace width (CW, distance between the fifth lateral spine tips) and carapace length (CL, midline distance from the diastema between the rostral teeth to the posterior carapace edge) were measured to the nearest millimeter. Additional characteristics such as the degree of carapace fouling and gonopore size and shape were also examined. Molt stages were based on a modification of stages presented by Beyers and Wilke (1980) for *G. quinquedens* (*G. maritae*; see Manning and Holthuis, 1981).

The presence and color of extruded eggs were recorded along with incidence of egg remnants on the pleopods. Each month, 25 eggs were removed from each of 5 females and the diameters were measured with an ocular micrometer. Evidence of copulation was determined by examination of gonopore margins and spermatheca contents.

Twelve females with stage C eggs (eye pigment visible; see Meredith, 1952) were examined for fecundity following methods adapted from Hines (1982). Pleo-

Table 1. Developmental stages of ovaries of *Geryon fenneri* including color variation and mea[illegible]e diameter by stage.

		Oocyte diameters (μm)		
Ovarian stage	Ovary color	Mean	Range	*N*
Immature	white transparent			
Early	ivory yellow yellow-orange	83.9	30.6–224	250
Intermediate	yellow-orange brownish orange brownish tan	154.8	30.6–352	250
Advanced	red-orange brownish tan purple-gray purple	243.3	96.3–354	250
Mature	purple-gray dark purple	387.8	110–535	250
Redeveloping spent	ivory tan yellow-orange	89.4	22.1–188	250

pods with attached eggs were removed and fixed in 10% buffered Formalin. After drying to constant weight at 60°C, the eggs were removed from the pleopods, carefully stripped of any connecting tissue, and weighed to the nearest 0.1 mg. Fecundity was estimated by extrapolation using the mean dry weight of 5 subsamples of 1,500 eggs and the dry weight of the total egg mass. The relationship between fecundity and carapace width was examined by linear regression analysis.

All females were dissected to examine gross ovarian condition with representative samples prepared for histological examination as described by Yevich and Barszcz (1977). Following 24-h fixation in Zenker-Helly's solution, tissues were processed, embedded in Paraplast®, and representative sections were cut at 6–8 μm. The resulting slides were stained with hematoxylin and eosin (Luna, 1960).

Developing oocytes were measured to the nearest micrometer on an image analysis system, consisting of a compound microscope equipped with a video camera, a digitizing tablet, and a microcomputer with analytical software. Monthly mean oocyte diameters were calculated from the measurements of 50 oocytes per individual using 14–22 animals per month.

In addition, observations on behavior, mating, and molting were made in the laboratory on crabs kept in captivity since December 1985. All animals were maintained in total darkness in two 40-gallon (151-l) refrigerated aquariums at 9.5°C and 36‰ salinity and were fed scallop meats and shrimp 3 times a week.

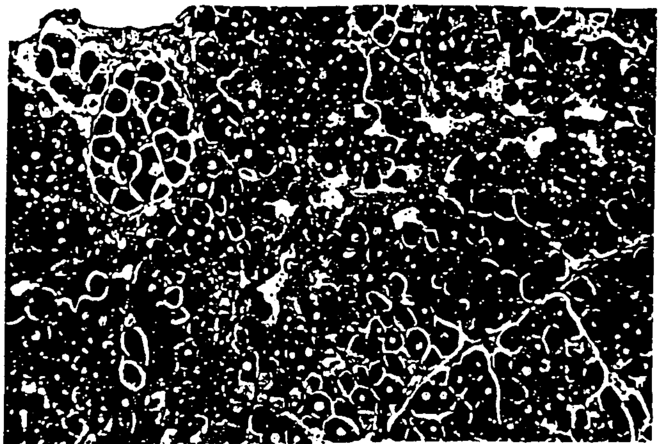
RESULTS AND DISCUSSION

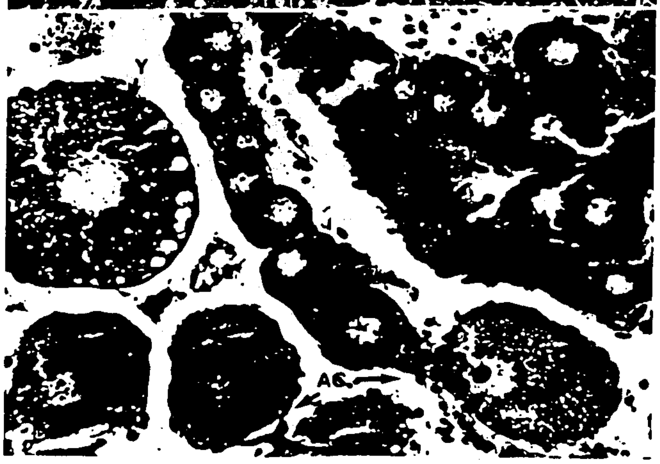
Ovarian Development

The ovary is similar in location to that of *Geryon maritae* (see Melville-Smith, 1987) and *G. quinquedens* (see Haefner, 1977). H-shaped in form, it lies dorsal to the hepatopancreas and extends posteriorly along each side of the hind-gut. Spermathecae, which arise from the midlateral portion, extend ventrally to gonopores that open on the sixth thoracic somite. Anterior to the heart, the ovaries join at a commissure just posterior to the stomach, with lobes that extend anterolaterally around the gastric region. The entire ovary is bound by fibrous connective tissue which serves to separate the organ from the surrounding hemocoel. Stages of ovarian development are presented in Table 1.

The immature ovary is white or transparent, less than 2 mm in diameter, tubular, and without pronounced lobation. Histologically, the medial germ strand is surrounded by abundant fibrous connective tissue and open spaces in the lumen. When visible, oogonia are in close proximity to the germ strand.

The early-stage ovary is characterized by an ivory, yellow, or yellow-orange color. Oocytes in various stages of early development are present, often bound by fibrous connective tissue to form small internal lobes. The germ strand is well defined, with oogonia and early-stage oocytes that radiate outwards and gradually fill the open spaces in the lumen (Fig. 1). Mean oocyte diameter at this early stage is 83.9 μm with a range of 30.6 to 224 μm.

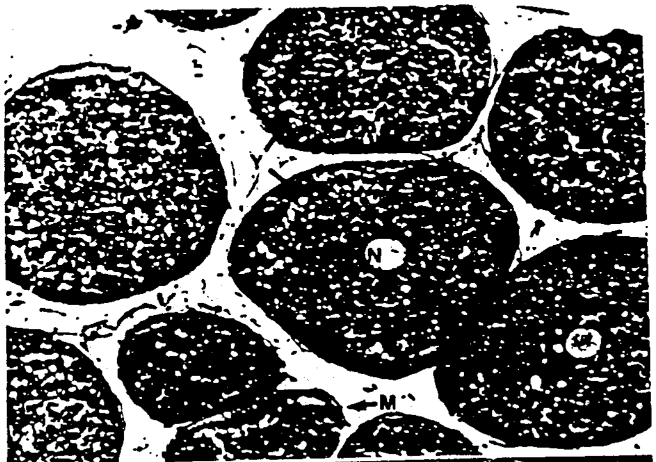




ig. 1. Early stage ovary of *Geryon fenneri* with germ strand (GS), oogonia (OG), and early stage oocytes (OC) diating out from germ strand (×25).

g. 2. Intermediate stage ovary of *Geryon fenneri* with accumulated yolk globules (Y) within developing oocyte id accessory cells (AC) surrounding oocytes undergoing early vitellogenesis (×160).

The intermediate-stage ovary is a yellow-ange, brownish orange or brownish tan olor. Advanced oocytes, many of which are itering the early stages of vitellogenesis, predominate at this stage. Numerous accessory cells are present and surround oocytes that are accumulating yolk globules (Fig. 2). Mean oocyte diameter at this stage



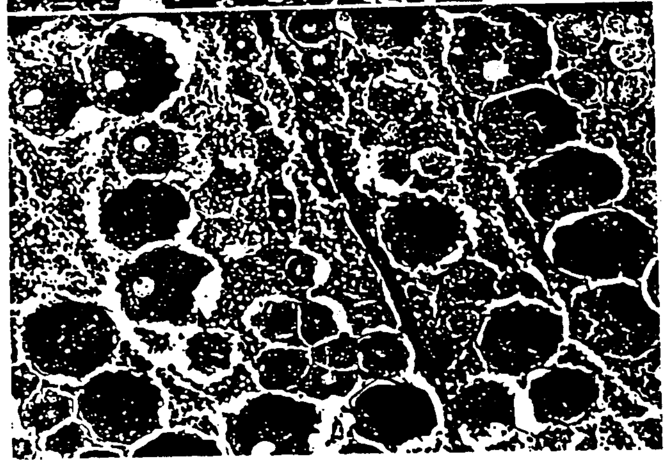


Fig. 3. Mature ovary of *Geryon fenneri* with prominent nucleus (N), yolk globules (Y), and chorionic membrane (M) of mature ovum (×63).

Fig. 4. Redeveloping ovary of *Geryon fenneri* with developing oocytes (OC) radiating from germ strand and numerous phagocytic cells (P) surrounding unspawned ova undergoing resorption (RO) (×63).

is 154.8 μm and developing oocytes range from 30.6 to 352 μm in diameter.

The advanced ovary is swollen with pronounced lobation, often obscuring the anterolateral portions of the hepatopancreas. Color varies from red-orange to brownish tan, gradually becoming purple-gray and purple in the latter portion of this stage. The

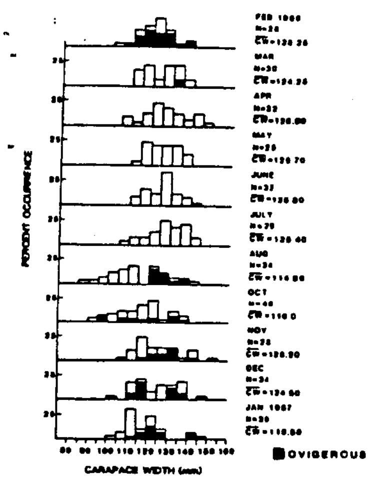


Fig. 5. Monthly size-frequency distributions of female *Geryon fenneri* collected at Fort Lauderdale, Florida, including number of individuals (*N*) and mean carapace width (CW). Solid areas indicate ovigerous females.

majority of oocytes are in the late phases of vitellogenesis and exhibit a granular texture arising from the accumulation of yolk globules. Accessory cells peripheral to oocytes are still present in the early vitellogenic stage. The oocytes have a mean diameter of 243.3 μm and range from 110 to 354 μm.

Mature ovaries are purple-gray or dark purple and the greatly swollen anterior lobes completely obscure the underlying hepatopancreas. The enclosing fibrous connective tissue is tightly stretched, often to the point of bursting during dissection. Mature ova are easily visible through this outer tissue layer.

Histologically, the ovary is dominated by mature ova which are granular in appearance due to the high concentration of yolk globules (Fig. 3). Vitellogenesis is essentially complete at this stage and the chorionic membrane surrounding each ovum is conspicuous. The germ strand is usually obscured by the tightly packed mature ova, and accessory cells are present only proximal to the few oocytes still undergoing tellogenesis. Mean diameter of the ova is 387.8 μm with the maximum size of 545 μm overlapping the sizes of initially extruded eggs (500–560 μm).

The spawned or redeveloping ovary is very flaccid, and ivory, tan, or yellow-orange. Unspawned ova may be visible through the outer fibrous connective tissue. The germ strand is well defined and oogonia and developing oocytes radiate outwards from this region (Fig. 4). The greater part of the ovary consists of fibrous connective tissue and hemal spaces containing blood cells and phagocytes. Mature unspawned ova undergoing resorption are often present surrounded by phagocytes.

Reproductive Cycle

The monthly incidence of ovigerous females examined indicates an annual reproductive cycle (Fig. 5). Oviposition begins in mid-August and continues through early October. Thirty-three per cent of females collected in August were ovigerous and had redeveloping ovaries, while 17% had mature ovaries prior to oviposition. In October, 29% were ovigerous with ovaries in either redeveloping or early developmental stages, while 8% had mature ovaries.

Eggs are carried for approximately six months after which larvae hatch during late February and March. Seven per cent of females examined in February and 57% from March had egg remnants on the pleopods. Larvae were hatched from two ovigerous females held in the laboratory during early March, but larval culture was not successful.

Analysis of mean monthly oocyte diameters further illustrates the annual reproductive cycle of *G. fenneri* (Fig. 6). The minimum oocyte diameter recorded in October coincides with the greatest incidence of ovigerous females with redeveloping and early-stage ovaries. Mean oocyte diameter gradually increased each month and reached a maximum during July, prior to the initiation of oviposition in August. Mean oocyte diameter of 188.2 μm recorded in August included both mature and spent ovaries.

The annual reproductive cycle of *G. fenneri* is markedly different from the continuous cycle reported for other species of *Geryon*. *Geryon maritae*, which occurs off West Africa (Intes and Le Loueff, 1976; Le Loeuff *et al.*, 1974) and Southwest Africa (Beyers and Wilke, 1980), exhibits no seasonality in the reproductive cycle based on visual and histological observations of the ovaries (Melville-Smith, 1987). Ovigerous *G. maritae* were collected in the majority of months; however, they composed less than 0.1% of the more than 9,000 females examined (Melville-Smith, 1987).

A continuous reproductive cycle has also been reported for *G. quinquedens* collected off the Mid-Atlantic coast of the United States (Haefner, 1977, 1978). Ovigerous females of that species were collected throughout the year, but based on ovarian stages and seasonal differences in egg development, a peak spawning season was suggested during the fall months. However, Ganz and Hermann (1975) suggested that oviposition in *G. quinquedens* occurs in late July and August with eggs incubated for approximately nine months before they hatch in May.

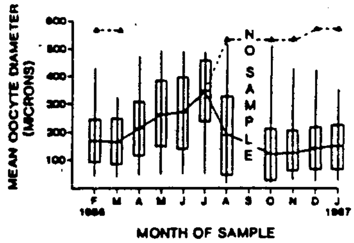


Fig. 6. Mean oocyte diameter in *Geryon fenneri* by month of sample, including standard deviation and oocyte diameter range. Triangles represent mean diameter of extruded eggs.

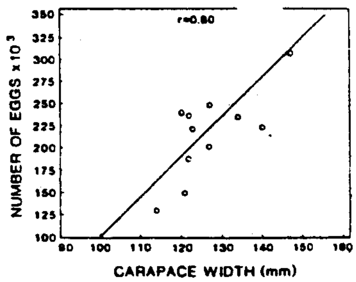


Fig. 7. Relationship in *Geryon fenneri* of brood size on carapace width as described by number of eggs = 4,465.7 CW − 346,105.

Fecundity

Mean egg diameter for *G. fenneri* is 540 μm at the time of oviposition. This increases with development to between 580 and 600 μm prior to hatching (Fig. 6). This size is within the range of 550 to 680 μm reported for eggs of *G. maritae* (see Melville-Smith, 1987), but less than the 630 to 850 μm reported for *G. quinquedens* (see Gray, 1969; Haefner, 1978; Hines, 1982).

Regression analysis of egg number on carapace width is shown in Fig. 7. The number of eggs per female increased with increasing carapace width as described by:

$$\text{Number of eggs} = 4{,}465.7\ CW - 346{,}105 \quad (r = 0.80).$$

Thus, the number of eggs extruded is directly correlated with the size of the female. Sizes of females examined ranged from 114 to 147 mm CW. Egg number for these females ranged from 131,000 through 347,000. This fecundity is comparable to estimates of 107,000–350,000 eggs reported for *G. maritae* (see Melville-Smith, 1987) and to values of 35,000–211,000 eggs for *G. quinquedens* (see Gray, 1969).

Eggs are light purple or burgundy after oviposition, gradually becoming dark purple and purple-brown prior to hatching. The color of initially extruded eggs and the changes observed during development differ greatly from the four color patterns reported for *G. quinquedens* (see Haefner, 1978; Wigley *et al.*, 1975). Eggs of that species are initially red-orange, becoming brown, purple, and black with further development.

Mating

Based upon observations of animals kept in captivity, mating of *G. fenneri* occurs during the period immediately following molting of the female, and is similar to that described for *G. longipes* (see Mori and Relini, 1982) and *G. quinquedens* (see Elner *et al.*, 1987). A female *G. fenneri* (91 mm CW) in the immediate premolt stage was col-

Appendix O. Reproductive Ecology of Female Golden Crabs, *Geryon fenneri* Manning and Holthuis, from Southeastern Florida

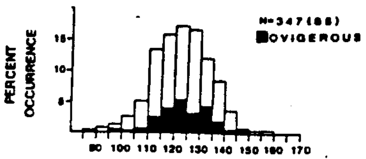


Fig. 8. Cumulative size frequency distribution of 347 female *Geryon fenneri* collected at Fort Lauderdale, Florida. Solid areas indicate ovigerous females.

lected in late July 1986 and held with other crabs in a refrigerated aquarium system (T = 9.5°C). Precopulatory behavior was observed beginning in mid-August when the male formed a protective cage around the female by using his walking legs. The male clasped the female, dorsal side up, with the first pair of his walking legs, while maintaining the ability to move about on the tips of his walking legs and to feed at regular intervals. The female did not feed during the period of the embrace. In the first week of September the female molted while the male formed an expanded cage around her. However, the molt was unsuccessful, since the female was unable to back entirely out of the old carapace; hence, mating did not occur.

Size at Sexual Maturity

In addition to the onset of ovarian development and the presence of eggs, other characteristics must also be considered in the assessment of the size at sexual maturity in brachyurans. Following the pubertal molt, the abdomen and gonopores show changes that are generally accepted as external morphological indications of sexual maturity (Hartnoll, 1969). Changes in the gonopores following the pubertal molt and accompanying mating have been reported for two species of *Geryon*. Haefner (1977) described six types of gonopores for *G. quinquedens* that included three forms on immature animals and three forms on mature animals. Three types are reported for *G. maritae*, two simple slitlike forms in sexually immature animals and a third gaping form present in sexually mature animals that have undergone mating (Melville-Smith, 1987).

Geryon fenneri exhibits the simple pattern of gonopores described by Hai (1967), with three distinct types recognized. Type A gonopores which are narrow and slitlike are present on sexually immature animals. Type B gonopores which follow the pubertal molt are elongate and ovoid in shape, while type C which is a modification of type B differs only in that the gonopore is more elongate and gaping as a result of mating during the immediate postmolt period. In addition, type C gonopores commonly exhibit a blackened margin due to abrasion by the male pleopods during mating. This discoloration has also been reported for *G. quinquedens* (see Haefner, 1977) and *G. maritae* (see Melville-Smith, 1987).

Carapace widths of the 347 females examined ranged from 89 to 156 mm. Eighty-seven females were ovigerous (25%) and ranged in size from 97 to 147 mm CW (Fig. 8). All ovigerous females examined exhibited type C gonopores (elongate and gaping) with 74% having blackened margins. Type C gonopores were also observed on nonovigerous females ranging in size from 103 to 156 mm CW, with 60% of the females examined having sperm present in the spermatheca. Thus, type C gonopores appear indicative of sexual maturity and previous mating. However, nonovigerous females with type C gonopores and empty spermathecae may have previously undergone mating and oviposition but have yet to molt and mate again.

Twenty-six females ranging in size from 89 to 118 mm CW were observed in the immediate premolt stages during August and October. All individuals examined had ovaries in the immature or early developmental stage and had type A gonopores. Recently molted females collected during the period of October through December exhibited signs of recent mating. Seventy-one per cent of females ranging in size from 105 to 120 mm CW had type C gonopores. Seven females were examined for spermathecal contents and five had sperm present. The remaining 29% of recently molted females had type B gonopores and empty spermathecae. Ovaries from all recently molted crabs were in either the early or intermediate stage of development.

Considering the changes in ovarian development associated with the annual reproductive cycle, recently molted females that successfully mated would be expected to undergo oviposition during August through October of the following year. Overall, the population of females shows an annual reproductive cycle. However, individual members may be on a biennial cycle involving molting and mating the first year with subsequent oviposition during the fall months of the second year. The size range of ovigerous females, the stages of ovarian development, and the changes in gonopores associated with the pubertal molt indicate that the size at sexual maturity of female *G. fenneri* is between 85 and 100 mm CW. Size at maturity reported for *G. maritae* is between 80 and 100 mm CW (Le Loueff *et al.*, 1974; Melville-Smith, 1987), while *G. quinquedens* reaches sexual maturity between 80 and 91 mm CW (Haefner, 1977).

Depth Distribution of Species of *Geryon*

Both *Geryon maritae* and *G. quinquedens* are segregated by size and sex with depth. *Geryon maritae* occurs at depths of 100–900 m off West Africa (Intes and Le Loeuff, 1976; Manning and Holthuis, 1981) and Southwest Africa (Beyers and Wilke, 1980). Females of this species are more common than males between 400 and 600 m, while males dominate at depths exceeding 600 m. Sizes of females increased with decreasing depth, with the same trend visible for males. Melville-Smith (1987) reported that the majority of ovigerous females were collected at depths between 400 and 600 m, with no ovigerous females recorded below 610 m.

This same pattern has been shown for *G. quinquedens* (see Haefner and Musick, 1974; Haefner, 1977, 1978; Wigley *et al.*, 1975). Males are abundant at depths greater than 500 m, while females are more numerous between 300 and 600 m. Segregation of size by depth is also reported for this species, with larger individuals observed in the upper range of their depth distribution. Haefner (1978) reported that crabs with late developmental stage eggs are more common in shallower depths, suggesting that migration by ovigerous females into somewhat warmer waters enhances egg development.

In southern Florida, both *G. fenneri* and *G. quinquedens* are major members of the continental slope fauna. However, a pronounced difference in depth distribution exists between the two species. ...on *fenneri* exhibits a continental distribution pattern and is limited to depths between 230 and 470 m. *Geryon quinquedens*, which undergoes tropical submergence south of Cape Hatteras, shows a deep slope distributional pattern and is more common at depths in excess of 700 m (Soto, 1985).

The contrasting reproductive patterns observed between *G. fenneri* and *G. quinquedens* may relate to the different geographical and bathymetric distributions of these species. The pronounced annual pattern and six-month egg incubation period of *G. fenneri* may result from the upper slope distribution of this species. The longer egg incubation period and protracted or continuous reproductive pattern of *G. quinquedens* may reflect the greater geographical range and deep slope distribution of this species.

Whether *G. fenneri* shows the same segregation of sex and size with depth as other species of *Geryon* remains unknown, although the majority of the crabs caught in the depth range (215–235 m) of the present study were males. Additional studies of the biology and distribution of *G. fenneri* and *G. quinquedens* may provide evidence for the differences in bathymetric distribution and reproductive patterns observed in these slope-dwelling species.

Acknowledgements

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POPULATION DYNAMICS OF THE CRAYFISH *PROCAMBARUS SPICULIFER* OBSERVED IN DIFFERENT-SIZED STREAMS IN RESPONSE TO TWO DROUGHTS

Robert C. Taylor

ABSTRACT

Crayfish (*Procambarus spiculifer*) were studied for 8 years in 3 different study sites. During this period 2 droughts occurred. Consistent changes were observed in response to both droughts and in all study sites. The changes included reductions in both mean body size and abundance and an increase in the juvenile to adult ratio. In response to the first drought, one of the subpopulations changed to a smaller mean body size that was maintained for 5 years (nearly 2 generations) until the second drought caused a second reduction in body size. It is postulated that the reduced size can be maintained by a continued loss of the largest size classes coupled to an increased recruitment of small adults. Two other subpopulations became extinct, one following the 1981 drought and the other during the 1985 drought. The population changes appear related to habitat differences between study sites, differences between reference years and drought years, and the time since the last drought.

Body size is an important determinant of an animal's energetic needs (Peters, 1983), ability to use available resources (Werner and Gilliam, 1984), and susceptibility to predation (Kusano, 1981; Polis, 1981). For some animals, size may be a better predictor of fecundity than is age (Kirkpatrick, 1984). Size-related correlations have been observed in crayfish populations. Their fecundity (Mason, 1963; Vannote, 1963; Prins, 1968; Shimizu and Goldman, 1983) and competitive success (Bovbjerg, 1953, 1956; Rabeni, 1985) increase with body size and susceptibility to predation decreases (Stein, 1977).

However, crayfish body-size distributions have been observed to fluctuate with habitat change, such as water depth. As the water depth decreases, in either a lotic or lentic habitat, the ratio of juveniles per adult increases and the adult mean body size becomes smaller (Caine, 1978; Kushlan and Kushlan, 1979; Taylor, 1983). Caine observed that mean body size was larger for *Procambarus kilbyi* in nondrying habitats, while simultaneously finding smaller mean body-size populations in areas that were drying. Rabeni (1985) observed a similar size-depth relationship in the crayfish *Orconectes punctimanus*. The size benefits, therefore, may be lost during low-water periods such as droughts.

The study areas that I have been sampling since 1979 experienced a severe drought in 1981 (Taylor, 1983). During observations of the recovery of a crayfish population (*Procambarus spiculifer*) following the 1981 drought, a second drought occurred in 1985–1986. The second drought provided an opportunity to replicate the subpopulation responses to a natural disturbance. Both droughts produced the predicted mean body-size changes to habitat drying. However, the changes in one subpopulation have been maintained for at least 2 generations. The droughts also resulted in a reduced population abundance and possible extinction of the species from one study site in 1981 and from a second in 1985.

This communication will present data on both the drought-related changes in the subpopulations of *P. spiculifer* and the post-drought population responses. I will further discuss the factors that contributed to the changes and the long-term postdrought effects.

MATERIALS AND METHODS

Study Area.—Crayfish were sampled in Sandy Creek, located on the Piedmont Plateau in Georgia (34°N, 82°21'W). The creek has a drainage basin of 165 km, a length of about 25 km, and a vertical drop from 262 to 185 m above mean sea level. The water has a pH of 5.5–6.5 and is very soft because it drains an area of metamorphic bedrock.

Sampling of the 2 study sites discussed in this communication was started in June 1979. One site was located 0.5 km above the creek's confluence with the North Oconee River (drainage area = 733 km²). At the study site, Sandy Creek is a fifth-order stream, 15 m

Appendix P. The Golden Crab (*Geryon fenneri*) Fishery of Southeast Florida (1988)

THE GOLDEN CRAB (GERYON FENNERI) FISHERY OF SOUTHEAST FLORIDA

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INTRODUCTION

The golden crab, Geryon fenneri (Manning and Holthuis, 1984) is a large brachyuran inhabiting the continental slope off the southeast United States including the eastern Gulf of Mexico. Prior to its description in 1984, studies in the eastern Gulf of Mexico by Otwell, Bellairs and Sweat (1984) examined the potential development of a trap fishery for this species in depths exceeding 210 meters. Various trap designs were tested along with methods of on-board handling and processing (Sweat and Otwell, 1983); Bellairs and Otwell, 1983). Particularly attractive was the reported high meat yield of male crabs, ranging from 17 to 23 percent of total body weight.

Interest in the commercial exploitation of golden crab led to three vessels (two from Alaska and one from New England) initiating a fishery along the west coast of Florida during late 1984. Male crabs were butchered, cooked and blast frozen at sea. The final product of clusters, cocktail claws and split legs were delivered frozen to the market. However, because of marketing problems, compounded by distances in excess of 100 miles to the fishing grounds, gear loss and the absence of information on the distribution and biology of this species, commercial operations in the eastern Gulf of Mexico ceased by mid-1985.

In late 1985, continued interest in the commercial potential for G. fenneri led to the initiation of exploratory fishing and research in Bermuda (Luckhurst, 1986), South Carolina (Wenner and Ulrich, 1986), Georgia (D. Harrington, personal communication) and Florida. Additionally, in late 1985 a small commercial fishery developed along the southeast Florida coast with the catch delivered live to a local market in Ft. Lauderdale, Florida.

In February 1986, we began a study of the biology of Geryon fenneri as collected from this southeast Florida fishery. Reproductive biology, size and weight relationships, trap design and catch per unit effort were examined to ascertain additional information relative to the study of this potentially valuable species.

METHODS

Gear previously utilized by the eastern Gulf of Mexico golden crab fishery consisted of deep water long lines of between 30 and 60 traps attached to a ground line connected via a float line to large floats and radar reflectors on the surface (Otwell, Bellairs and Sweat, 1984).

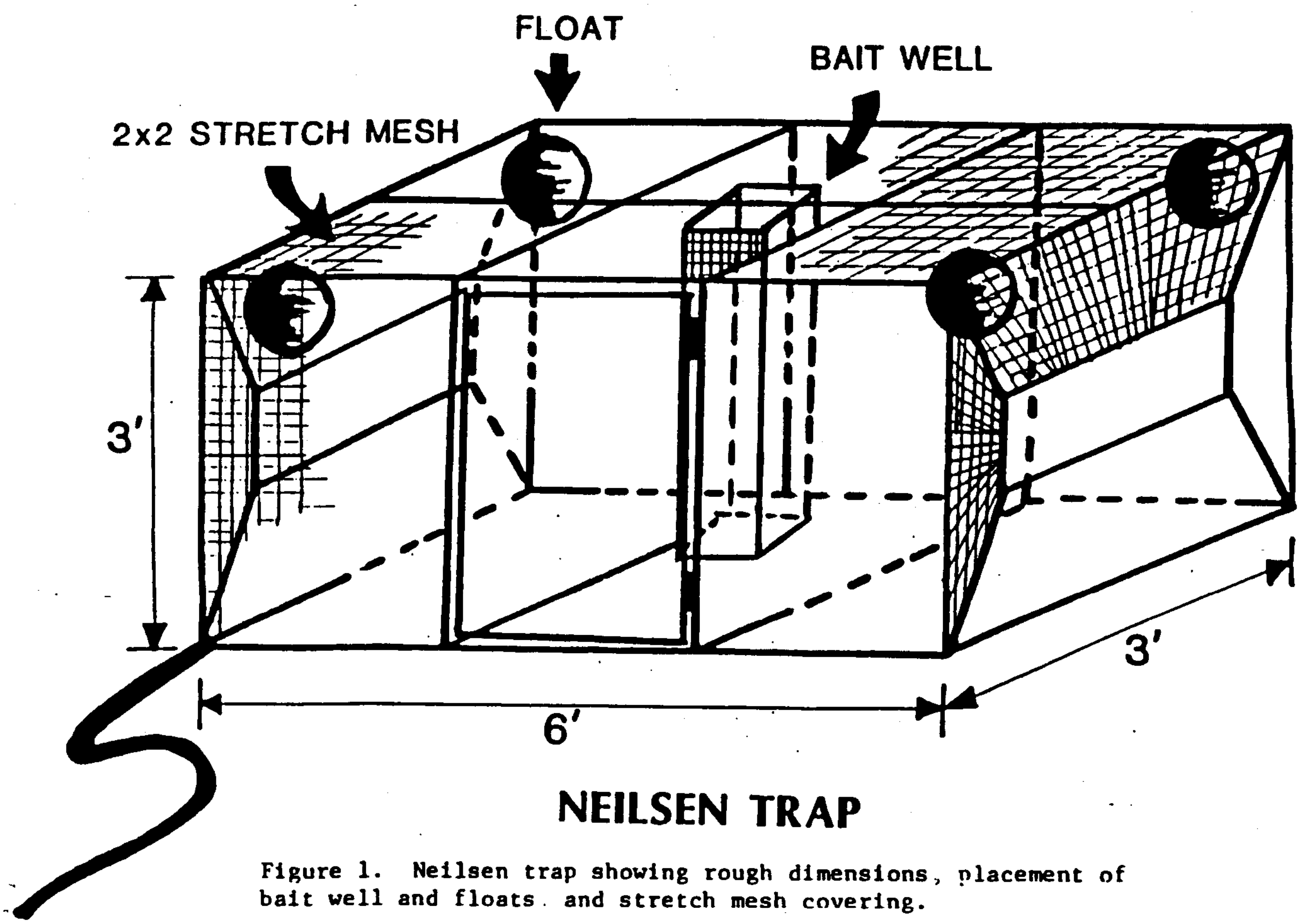
This method requires the capability to retrieve upwards of one mile of line from depths in excess of 250 meters. Trap designs have included Dungeness crab pots, King crab traps, New England and Florida lobster traps and plastic Fathoms Plus traps (Otwell, Bellairs and Sweat, 1984; Wenner and Ulrich, 1986). Three or four trap lines were fished with soak times averaging 24 hours between set and retrieval.

Because of the close proximity to shore (less than 10 miles) of water depths in excess of 200 meters, the small fishery that has developed in southeast Florida employs a different strategy in harvesting golden crab. Four to six large traps are attached approximately 140 to 180 meters apart to a ground line which is fitted with concrete weights on each end. The large traps called Neilsen traps, measure approximately 6' x 3' x 3' and are made from steel round stock covered with 2" x 2" nylon stretch mesh (Figure 1). Traps are fitted with 5" diameter escape rings and a large side door providing access to the center bait well and easy removal of the catch. Four to six strings of traps may be fished, with each string reset immediately after it is pulled.

As the present fishing grounds are adjacent to commercial shipping lanes and affected by variable currents associated with the Gulf Stream, trap lines are deployed without a surface float system. Loran coordinates are recorded during deployment along with bottom profiles and relative position using shoreline landmarks. Soak time varies from three to six days depending on market demand. This allows the fishermen to pursue other commercial opportunities. Trap recovery involves grappling for the ground line, with the vessel moving from offshore to onshore and the grapnel dragged perpendicular to the ground line.

Samples were collected monthly during the period February 1986 through January 1987 from fishing depths ranging from 215 to 230 meters. Total numbers of crabs caught per trip were recorded in three categories: females, market size males in excess of 130 mm carapace width (CW), and small males less than 130 mm CW. Crabs were randomly selected from the catch, packed in crushed ice and returned live to the laboratory.

For each crab, carapace width (CW, the distance between the fifth lateral spine tips) and carapace length (CL, midline distance from the diastema between the rostral teeth to the posterior carapace edge) were recorded to the nearest millimeter. Weight was recorded to the nearest gram and missing appendages noted. The presence of eggs in pleopods were noted and molt stages were estimated according to a modification of stages presented in Byers and Wilke (1980) for G. quinquedens (probably G. maritae; see Manning and Holthuis, 1981). Weight-width relationships of animals in the intermolt stage and with no appendages missing were calculated using a log-log transformation expressed in the form $Y = aX^b$.



NEILSEN TRAP

Figure 1. Neilsen trap showing rough dimensions, placement of bait well and floats and stretch mesh covering.

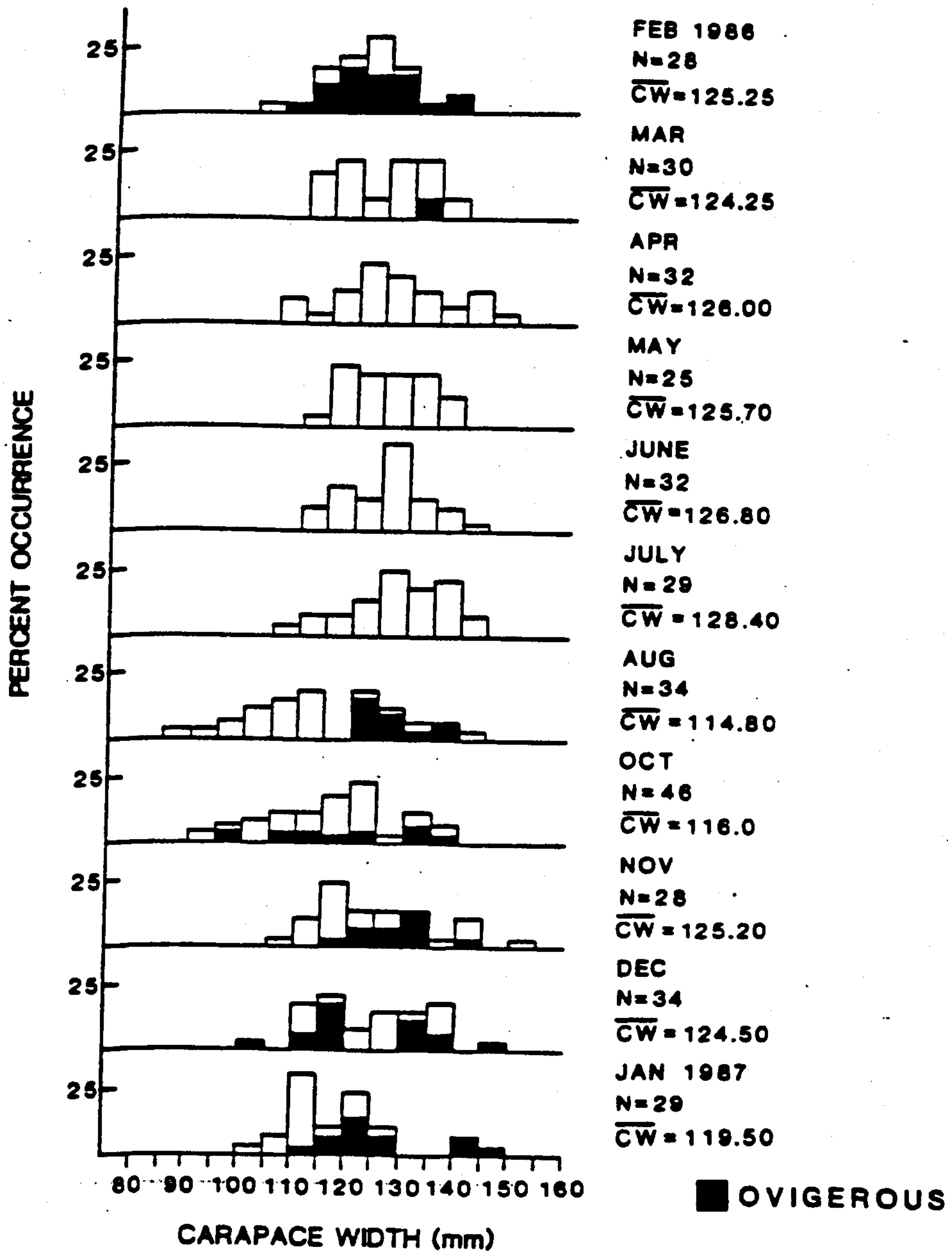


Figure 3. Monthly size frequency distributions of female Geryon fenneri including number of individuals and mean carapace width. Ovigerous females are shaded.

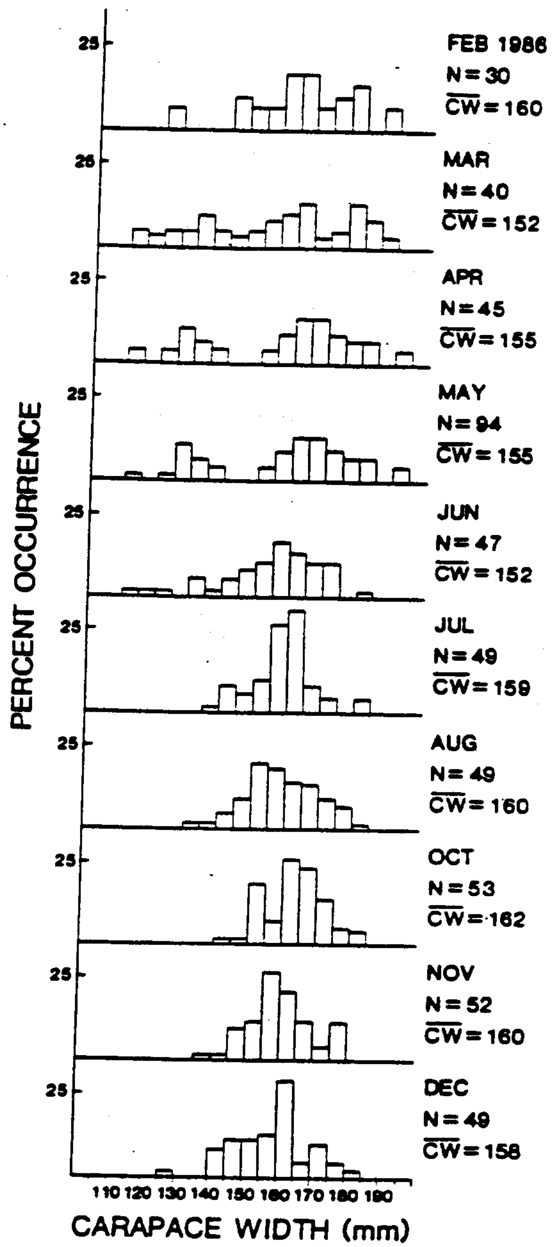


Figure 4. Monthly size frequency distributions of male Geryon fenneri including number of individuals and mean carapace width.

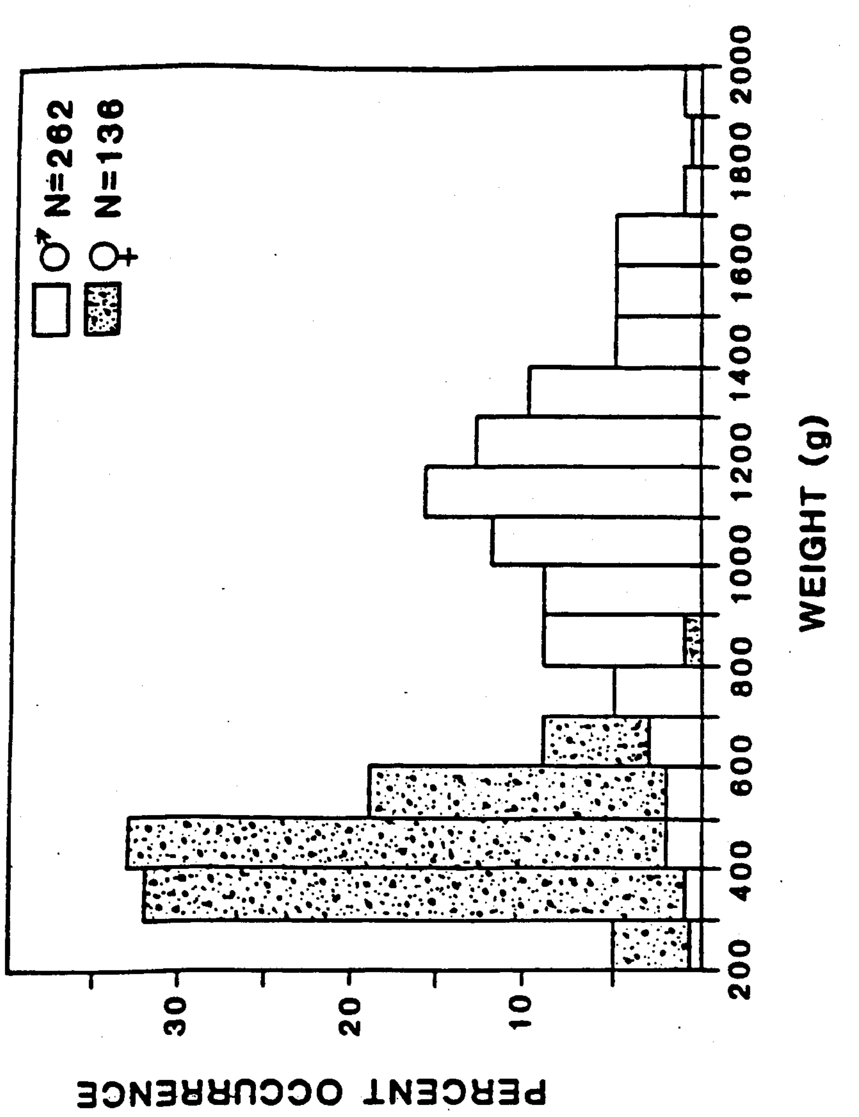


Figure 5. Cumulative weight frequency distribution of male and female <u>Geryon fenneri</u> collected during the period February 1986 through January 1987 from Ft. Lauderdale Florida.

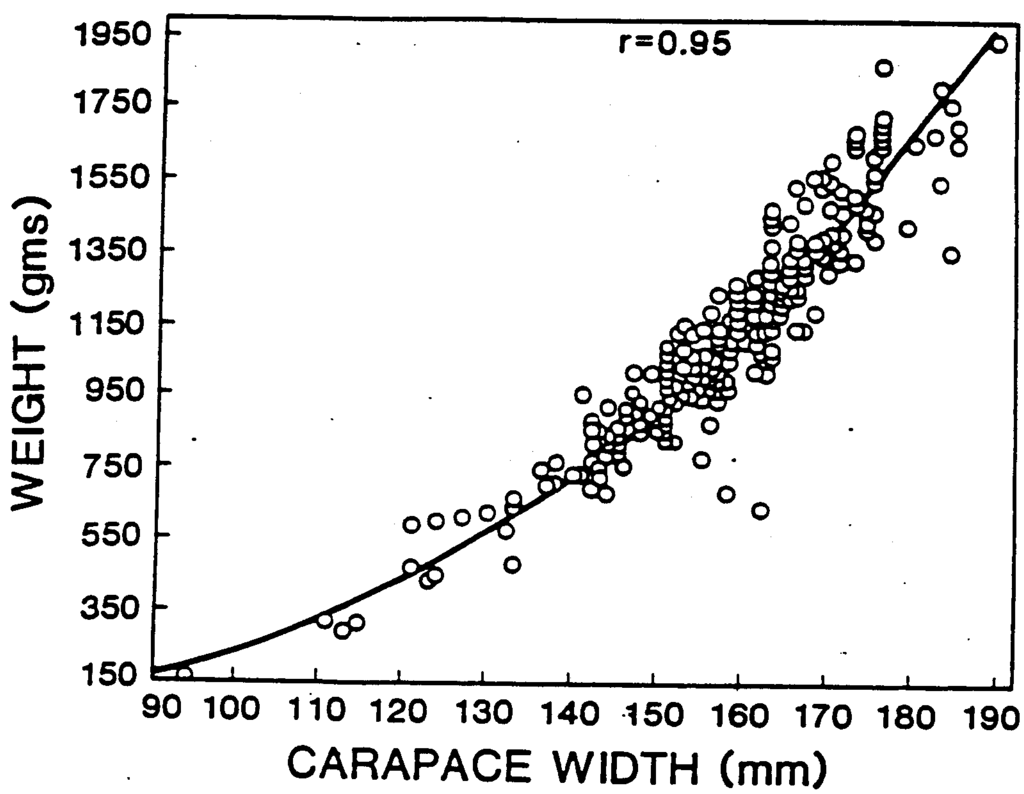


Figure 6. Weight on carapace width relationship for 262 male *Geryon fenneri* as described by WT = $5.27 \times 10^{-5}(CW^{3.328})$.

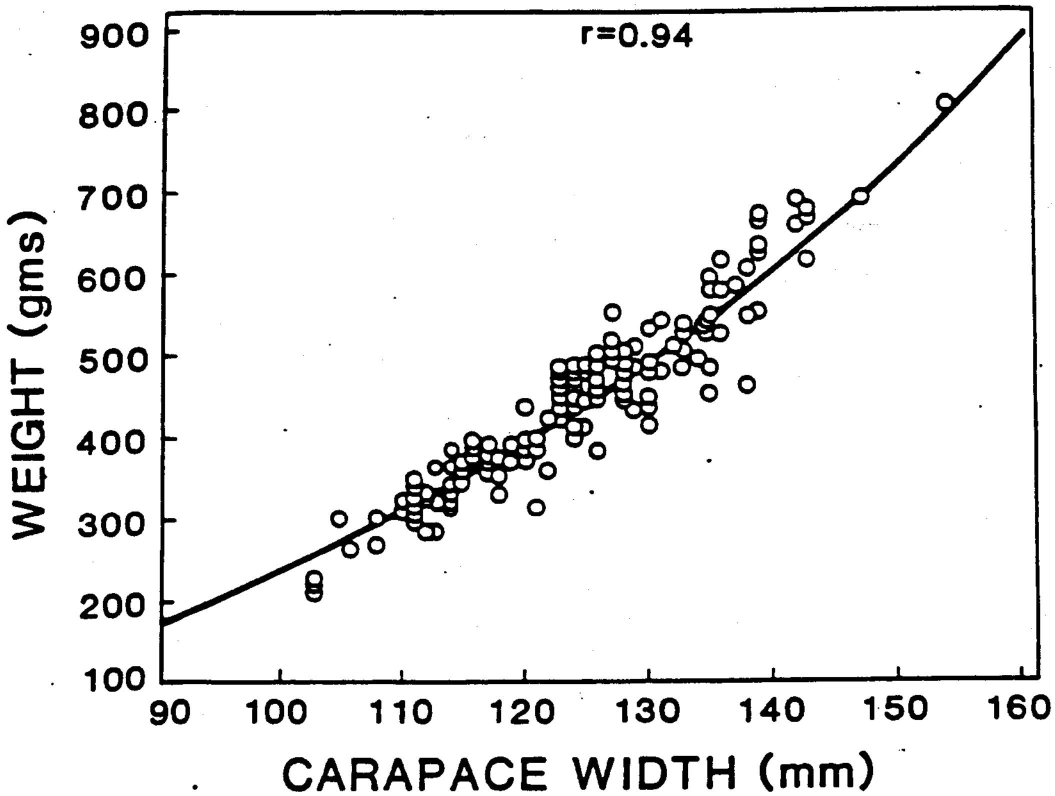


Figure 7. Weight on carapace width relationship for 136 female <u>Geryon</u> <u>fenneri</u> as described by $WT = 5.599 \times 10^{-4}(CW^{2.812})$.

DISCUSSION

Geryon fenneri is considerably larger than *G. maritae* and *G. quinquedens*, two additional species of commercial value. As male *G. fenneri* attain a maximum size in excess of 190 mm CW and weight up to 2000 g, interest in commercial utilization is warranted. At present, the small fishery for this species is unregulated, with no closed season, quota or minimum size limits on harvestable animals. In the southeastern Florida fishery, only males greater than 130 mm CW are utilized, and all females and small males returned to the water. Considering the annual reproductive pattern of females and the slow growth associated with organisms of large size from this deep water environment, the voluntary practice of selective harvest is undoubtedly of benefit in protecting the potential longevity of this fishery.

The strategy employed by the golden crab fishermen of southeast Florida has proven successful in providing a sufficient amount of product to local markets. The use un-buoyed trap lines with few large traps and long soak times has resulted in the development of a small scale local fishery, with fishermen able to pursue other commercial opportunities rather than fish crab exclusively. The close proximity of the fishing grounds to shore permits delivery of live product thus eliminating on-board processing and storage. This in turn reduces the cost per trip on the basis of fuel, labor and processing equipment. Live product is also more attractive to the consumer, who is able to purchase whole live crab or freshly butchered and cooked clusters rather than pre-cooked, frozen crab.

The full commercial potential of this species will remain unknown until such biological data as population density, reproduction patterns and geographical distribution, which are still under study, are collected and fully analyzed. Additionally, future research should continue to address gear development, trap design and the use of escape rings. Although the small southeast Florida fishery has been relatively successful, the longevity and potential expansion of the fishery for this valuable species remains unknown and over-capitalization by fishermen wishing to enter this fishery should be discouraged.

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Appendix Q. Market Report: North Pacific Crab (National Fisherman, October 1998)

NATIONAL FISHERMAN OCTOBER 1998

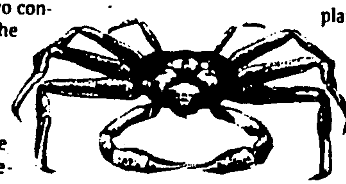
MARKET REPORT

NORTH PACIFIC
CRAB

Domestic opilio market improving, but king crabbers yearning for yen

The slip-sliding value of the Japanese yen will play its dismal hand in the setting of this season's red king and opilio crab prices in the Bering Sea.

With the yen in July hovering at around 140 to the U.S. dollar, the market for red king crab in Japan grew so weak that one Tokyo-based wholesaler who got stuck with inventory reshipped two container loads back to the United States.



Though we're talking less than 80,000 pounds of red king crab, the anecdote epitomizes a wholesaler's plight — especially when one considers the cost of shipping the crabs both ways.

Cheap yen don't bode well for the upcoming king crab season for two reasons, says Will Blades, president of Royal Aleutian Seafoods.

For one, if nothing bolsters the value of the yen by September's opening, it's not likely many Japanese bidders will enter the arena. Second, their absence sets up domestic outlets for lower ex-vessel offerings.

"There goes the domestic market, if they can't buy," Blades says.

The outlook for opilio crab, the Bering Sea's predominant crab crop, is brighter.

"The domestic market is very strong," he says.

Again, the Japanese buying power will be a factor this winter when it comes time for setting the ex-vessel prices, but U.S. markets have proved that they could absorb more volume.

This was demonstrated two years ago, when the yen was considerably stronger and the Bering Sea quota was larger. The Japanese resisted buying, hoping the domestic market wouldn't be able to absorb the harvest and prices would hit bargain lows.

"They thought the market would choke on the volume," Blades says. "They planned to wait it out."

Instead, the United States saw record shipments of crab from Alaska's Dutch Harbor to cold-storage holdings in Tacoma, Wash.

Four years ago nearly all containers of frozen opilio went straight to Japan; now about 90 percent of the harvest winds up in cold storage.

"There has been a significant change in the initial shipment of crab," says Ken Zueger of SeaLand Services Inc. in Dutch Harbor.

Last year, Zueger says, 2,000 container vans went to Tacoma. The strategy among processors has been to ship the containers south for two reasons: It centralizes the product for shipping to either market, and storing the crab on U.S. soil sends a message to the Japanese that processors have other outlets.

The bad news, as any crabber will lament, is that switching the catch to the domestic market has done little to recoup the ex-vessel prices the fleet enjoyed in better times of trading with Japan.

While major buyers like Red Lobster were snatching up the processed opies (they market them as snow crab) for around $2.60 per pound and turning out all-you-can-eat specials for $9.99, crabbers received only 79 cents per pound for their opies in '97 and 58 cents earlier this year.

Crabbers wanting to ante up for the '99 season can expect prices to start out about the same, unless the Japanese economy recovers.

Fishermen plying the waters for either crab species could benefit from anything that boosts the yen, but don't look for miracles anytime soon.

The United States sold off $2 billion in yen earlier this summer in hopes of resuscitating Japan's economy, with little result.

Still, America seems to be eating more snow crab each year.

Wain Jackson, retail marketing director with the Alaska Seafood Marketing Institute, walks the aisles of grocery stores every day and says that grocery giants are moving larger volumes, small markets are getting into the snow crab for the first time, and restaurants that used to crowd the crab in with other offerings on the menu now offer it as a feature item.

Why the interest in opies?

"The price points have been very attractive," says Jackson — so attractive that large grocery chains are making "power buys" at the corporate level, then shipping the goods off to regional divisions.

One distributor bought 2.3 million pounds in one sale, which is a little less than 10 percent of last year's Bering Sea opilio harvest.

Safeway, Hooters, Red Lobster, Club and Albertson's are among buyers in the Pacific Northwest, while Winn-Dixie has been a taker in the South.

Counter prices have been hovering near $4 per pound.

— *Charlie Ess*

Domestic opilio market surges